THE METRIC SYSTEM

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The Metric and British Systems of Weights, Measures and Coinage

BY

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LONDON

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PREFACE

IN commencing the study of science it is found necessary, or at any rate of great advantage, for the student to obtain a mastery of the metric system of notation. Having had to teach the metric system for a number of years, I have often wished for a small book upon the subject which could be placed in the hands of a student, and not being able to find exactly what I desired, this little book has been written with the hope that those engaged in teaching Chemistry, Physics, Engineering, or General Elementary Science may find it useful to put into the hands of their students.

In order to make it of more general application, especially in schools and polytechnics, a chapter upon specific gravities has been added, and also upon the use of the balance, as this should simplify the teaching of the subject to large classes.

A large number of arithmetical examples have not been inserted, but in each case one (or more), worked example has been given, so that the student can easily work out other examples for himself. Furthermore, by not multiplying examples, the teacher will not be bound down by examples which do not suit his special class of student, and will therefore have a freer hand and can himself set examples which have a special application to the students with whom he has to deal.

Not only is this little book intended for those engaged in the teaching profession and their students, but I venture to hope that it will be found useful to the business man and to the general public. In the introduction, reasons for the adoption of the metric system as a "National System" in this country, and subsequently as the "International System," are given. The notation is so simple and the working so easy, that if it were more thoroughly and generally understood, many of us are sanguine enough to believe that in course of time—and that not very far distant—we, as a nation, would throw away our complicated, ambiguous and cumbersome methods, and adopt the time and error-saving decimal system.

I desire to thank my colleagues, Messrs. W. Knowles, B.A., B.Sc. and H. Nutton, for suggestions and for looking through the sheets for me.

F. M. P.

Borough Polytechnic Institute,
London, S.E.
1907.

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INTRODUCTION

SURELY if iteration and reiteration by our Consular service, by business men abroad, by very many business men in this country, especially those whose business brings them into contact with foreign nations, by those engaged in science, and others who have the welfare and commercial supremacy of the British nation and her colonies at heart, could force us to use a simplified system of weights and measures, the metric system would long ago have replaced our cumbersome, brain-fatiguing, and crude system of weights and measures, or rather want of system of weights and measures.

Why, except as a feat in mental gymnastics, should we have one system of weights for gold, another for medicines, and a third for weighing ordinary commodities? and in each of the three systems we use the same names, ounce and pound; yet the pound Troy only contains 12 ounces, whereas the pound Avoirdupois contains 16, and to make confusion worse confounded, the ounce Troy is not the same as the ounce Avoirdupois. Drugs are purchased by Avoirdupois but compounded by Apothecaries' weight.

To take another example, the *stone* weight for human beings is 14 lb., but when the butcher weighs his dead carcases, the stone is only 8 lb., and for weighing glass it is 5 lb.

Surely it is unnecessary to have a different name for each quantity of a liquid? Thus a *firkin* is 9 gallons, an *anker* 10 gallons, *kilderkin*, *rundlet* or *half-barrel* is 18 gallons, a *barrel* 36 gallons, a *tierce* 42 gallons, and so on. How much simpler it would be if we took the *liter* as our standard and simply spoke of 10, 20, 50, 100 liters and so on, the 100 liters being a *hectoliter* and after the hundred, two, three, and so on hectoliters.

Again, how excessively complicated are our measurements of length. We have, for example, the *hand* equals 4 inches, *fathom* equal to 6 feet, *cable's length* equals 100 fathoms, 8 *furlongs* to the mile, and so on. In the metric system we start with the *meter*, which is divided into tenths, or multiplied by tens. The divisions of the meter thus become decimals of the meter.

How it must astound the foreigner accustomed to use the metric system, and also astonish many in this country, to learn that a bushel of corn in Shropshire weighs 72 to 75 lb., in Sunderland it is only 46 lb., while in Hereford it is 63 lb. Or again, in the case of potatoes, in Cornwall a bushel of potatoes weighs 224 lb., while in Nottingham it is only 84 lb. The chief absurdity here is employing the bushel for weights, because the bushel is really a measure of capacity and contains 8 gallons.

The whole of the metric system may be summed up in the following short table.

LENGTH. METER (m.) divided into 100 centimeters (cm.) or 1,000 millimeters (mm.).

LENGTH.	KILOMETER (km.) or 1,000 meters.
	There is also the decameter (Dm.) containing 10 meters and the hectometer (Hm.) 100 meters, but these terms are rarely employed. It being more usual to speak of 10 meters or 100 meters.
SURFACE.	SQUARE METER, divided into 10,000 square centimeters.
BULK.	CUBIC METER, divided into 1,000 cubic decimeters.
CAPACITY.	LITER, divided into 1,000 cubic centimeters.
WEIGHT.	GRAM, the weight of 1 cubic centimeter of water at the temperature of 4° Centigrade.

In the British system the conversion of the various weights and measures into each other is a tiresome and tedious operation, and requires the use of compound arithmetic. No compound arithmetic is required with the metric system. Lord Kelvin says that *our weights and measures are time wasting and brain wearing.*

Everyone knows how difficult it is at school to master the different systems of weights and measures which are in vogue in our various trades and businesses. And after all the waste of time and patience, how many persons when they have left school for a short time, would, if not engaged in the corn trade, for example, have any idea of corn measure? The senior mathematical master at the Edinburgh High School wrote, and his words were quoted by Lord Belhaven in the House of Lords, when asked his

opinion upon the waste of time involved in teaching the British system of weights and measures:

"An average scholar would save at least a year and a half, probably two. This saving is great in itself, but if it be considered how much he saves by not being subjected to a wearisome process of acquiring knowledge, say to convert ordinary yards to poles and *vice versa*, or square yards to perches and give a rational remainder, and the wearing out of the nervous system—not to speak of the teacher's—I conceive it to be not only a saving of time, but an economy of mental effort which is incalculable."

Nor is he alone in his opinion; nearly every master who has been approached on the subject has stated that at least one year of every child's school life is wasted by the use of our system of weights and measures; a waste to which those trained abroad, who in later life are to be our competitors, are not subjected.

And if after all this waste of time we ourselves do not know our own complicated system, how can we expect our neighbours and competitors, in trade, abroad to master the details? If every nation employed its own pet system, which differed from that of all other nations, we as a commercial nation would not be handicapped or put upon a different footing from our rivals. But what are the facts of the case? Almost every nation with which the British Empire trades, and especially her greatest commercial rivals, employs the metric system. Consequently, they have no difficulty in quoting with or against each other, but find it tiresome and difficult to convert the British systems into the metric

system. Our Consuls abroad continually sound warnings, but in most cases these warning cries fall upon deaf ears. The British Consul at Amsterdam said, in a report dated February, 1900:

". . . I may mention, as an undoubted fact, that the preference which Germany has obtained here over Great Britain as regards railway bridges and other railway material, is mainly owing to the existence of this metric classification."

In the Consular Report from Brazil in 1906 we find:

"The English system of weights and measures is a great drawback to obtaining the proper recognition in Brazil of the qualities of British manufacture. . . . The adoption of the Metric System by British manufacturers would greatly benefit trade with Brazil."

Again, from the Consular Report from Algeria:

"One of the greatest drawbacks to British trade in this colony is the antiquated system of British weights and measures. Millions are lost annually to British manufacturers by not adopting the Metric System and by not quoting prices in the moneys of the countries to which they wish to export their goods, as is done by Germany and other countries."

Mr. Arthur Chamberlain, Chairman of Kynoch's Ltd., said on 17th October, 1906, in an interview in "The Tribune":

"The English trade suffers immensely more in its foreign business from its weights and measures and its pounds, shillings and pence, than it does from the language. It is much easier for a foreigner with a small acquaintance with our language to understand

our catalogues in English, than it is to deal with the terrible confusion of dealing with pages of sizes and weights. *Buyers are deterred ten times more by this confusion than by reason of the catalogues being printed in English.*"

Our COLONIES realize the importance of the use of the metric system, as is shown by the resolution passed at the Colonial Conference in 1902, in which the Premiers of the self-governing Colonies said:

"It it advisable to adopt the metric system of weights and measures for use within the Empire, and the Prime Ministers urge the Governments represented at this Conference to give consideration to the question of its early adoption."

Quite recently, the Transvaal appointed a Commission to consider and report upon a Draft Ordinance to consolidate and amend the Law relating to Weights and Measures. In the report which was issued in 1906 great stress is laid upon the importance of adopting the metric system, not only because it is so simple, but also owing to the difficulties experienced in trading with foreign countries. But it is recognized that as the United Kingdom is their chief market, it would be a difficult matter for them to adopt it, if it were not first taken up by the Mother Country. They intend, however, to urge its adoption upon the United Kingdom, and say:

"The United Kingdom is conservative, and unless this is forced upon them, it will *never* be adopted."

Surely those who desire the welfare of our Colonies and their trading success with the nations of the world, will urge upon our Government and many of our own business men and traders, who also

require conversion, the importance, in fact the *absolute* necessity, of making the metric system compulsory.

Is it not time that we who lead the world in commerce and civilization adopted a system which could not but accrue to their advantage, and take a lead which would be bound to be followed by all other nations who have not yet adopted the metric system? And, after all, it is for our own convenience and gain. Lord Kelvin stated in his evidence before the Committee on Coinage, Weights, and Measures, appointed by Imperial Parliament:

"I believe I am not overstating the truth when I say that half the time occupied by clerks and draughtsmen in engineers' and surveyors' offices—I am sure at least one-half of it—is work entailed upon them by the inconveniences of the present farrago of weights and measures. The introduction of the French metrical system will produce an enormous saving in business offices of all kinds, engineering, commercial, and retail shops.

"NOTHING CAN BE MORE CONVENIENT THAN THE FRENCH METRICAL SYSTEM FOR EVERY KIND OF BUSINESS AND SCIENCE. THERE IS NO CASE, LARGE OR SMALL, IN RESPECT TO MEASUREMENT, WHERE THE FRENCH METRICAL SYSTEM IS NOT SATISFACTORY."

One often hears the Chauvinistic cry, "The British system for the British Empire"—it is worthy of note, however, that the Colonies do not as a rule join in this cry—and we are told: If you must have a decimal system, why not decimalize the inch? Very well, decimalize the inch; but where is the ratio between the decimalized inch and the foot which contains twelve inches and the yard which is three

feet? Or are we to take as our standard of weights a decimalized Troy Weight or a decimalized Avoirdupois Weight? (It would be comical to see either of them decimalized.) If the Empire-makers had been Chauvinists, where would our Empire have been to-day? The British Empire, upon which, we proudly boast, "the sun never sets," has been made what it is by assimilation of *the best* from all the provinces and principalities which have been annexed.

Is the nation to be looked upon as being of so dense a fibre that the population cannot learn a simplified form of weights and measures? At any rate, one often hears the opponents of the metric system base their opposition upon the difficulty of getting the nation at large to understand anything new, and upon the probability of those who know using their knowledge to cheat their less favoured neighbours. What a nation of cheats and harpies we must be!

We are told that millions would be lost to the engineering and other trades by an alteration of the standards already in existence. Yet, at the present moment, many firms who cater for the home and foreign market find themselves compelled to work to two standards—the old-fashioned and antiquated British and the metric system. If they did not they could not compete abroad at all.

All reforms mean hardships and difficulties to some one or other for a time while the transition is in progress. Should we therefore have no reforms? The advent of machinery led to hardships to some, and in all cases, even in the present day, when labour-saving machinery is introduced, there are those who temporarily suffer. But, after all, the

great principle which does and must govern the world is—the greatest good to the greatest number.

Changes should not be made abruptly, but should be gradual, so that the minority who are adversely affected should be as small as possible, and should be injured for as short a period as practicable.

Parliament has again rejected a bill brought forward to make the metric system compulsory, and therefore it is essential that the nation should be further educated up to the importance of a uniform international system of weights and measures. It was actually stated in the debate upon the bill that if we were to adopt the metric system it would be made easier for those who do not understand our present system to compete with us, and they would therefore be more readily able to get their goods into this country than at present. But even if they were, and this is problematical, we should also be more easily able to carry out transactions with them.

At present it seems very difficult to get a bill through Parliament, the object of which is to make the metric system compulsory, but surely it would be possible to pass a bill which would make the teaching of the system compulsory in every school in the land.

THE METRIC SYSTEM

MEASUREMENTS OF LENGTH

THE METER,[1] or unit of length adopted in the metric system, the name of which is derived from the Greek word METRON, a measure, is defined as the length at 0° Centigrade,[2] between two marks engraved upon a certain platinum bar kept in the Archives at Paris.

The meter was intended to be the one ten-millionth part of the quadrant of the earth's circumference, *i.e.*, the ten-millionth part of the distance between the Pole and the Equator, measured through Paris. This is illustrated diagrammatically in fig. 1.

The meter, therefore, supposing that no mistake had been made in the measurements is one ten-millionth part of the line *a b* (fig. 1). But since the original measurements were carried out it has been found that a slight error was made in the calculations and that the meter is slightly too short. The difference, however, is so slight that it would require a microscope to detect it. But in any case this very slight error does not in any way detract from the

[1] The spelling lit*er*, met*er*, instead of the French litre, metre, adopted in this book, is that employed by the Decimal Association, and is also used by the Americans.

[2] 0° Centigrade is the temperature of melting ice.

value of the metric system, because, as we have already seen, the meter is defined as the length at 0° C. between two marks upon a bar of platinum kept in Paris. Therefore, as this length is taken as the standard, and is always the same whether measured in Paris, London, Berlin, or New York, and there are standards which have been made of exactly the same length as the Paris meter kept in the chief

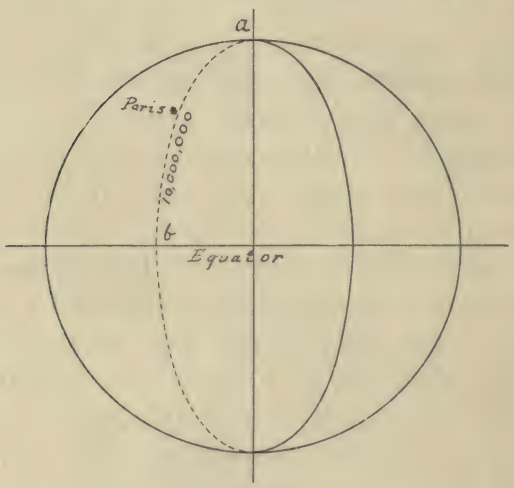


Fig. 1.

capitals of the world, it does not matter in the least what it was originally measured against.

We will now describe the metric system in detail. Fig. 2 is a scale sketch of the tenth part of a meter rule, and is the actual size. It will be noticed that it is divided into ten equal parts, and each tenth part is again divided into ten other equal parts. Now, as this is only one-tenth of a meter rule, the actual rule must contain 100 of the larger divisions,

i.e., 10 times 10; and 1,000 of the smaller divisions, that is, 10 times 100, because in the tenth part of the rule there are 100 of these smaller divisions.

The actual meter rule is subdivided into ten equal parts called DECIMETERS, from *decem*, the Latin for ten. These ten parts are again each subdivided into ten parts, and these are called CENTIMETERS, from *centum*, the Latin for one hundred. These in their turn are, as we see in fig. 2, divided into other ten parts called MILLIMETERS, from *mille*, a thousand. It is now possible to construct a table for the divisions

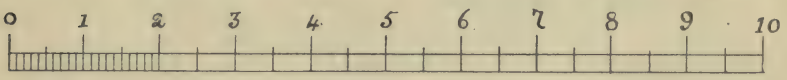


Fig. 2.

of a meter, or a table of linear measure. The abbreviations are written in brackets.

TABLE I

1 Millimeter (mm.) equals	$\frac{1}{1000}$	of a meter, or in decimals								0.001
1 Centimeter (cm.)	„	$\frac{1}{100}$	„							0.01
1 Decimeter (dm.)	„	$\frac{1}{10}$	„							0.1
1 METER (m.)	...	...	...	...	...	...	...	...	...	1.0
1 Decameter (Dm.)	...	...	...	...	...	...	= 10 meters			
1 Hectometer (Hm.)	...	...	...	...	...	...	= 100	„		
1 Kilometer (Km.)	...	...	...	...	...	...	= 1000	„		

In ascending measurements, for example from millimeters to centimeters, etc., it is only necessary to multiply by 10, or simply to place a decimal point one place to the left. Thus, 102 mm. is 10.2 cm., is 1.02 dm., and 0.102 of a meter.

On the other hand, to pass down from meters to decimeters, etc., add a nought to the end of the ciphers, or if a decimal point is already there, re-

move it one place to the right. Thus, 13864 meters = 138640 dm. = 1386400 cm. = 13864000 mm. Or, 383.624 meters to millimeters = 383624 mm.

As one not accustomed to employ the metric system of measurements is inclined to think in inches, feet, and yards, it may be as well in the first place to give a table of comparison between the British measurements of length, and those employed in the metric system. The exact numbers are given to the full number of decimal places, but the approximations which for all practical purposes may be used are placed in brackets.

TABLE II

1 Inch	=	25.39954113 mm. [25.4]
„	=	2.539954113 cm. [2.5]
1 Foot	=	30.479449 cm. [30.5]
1 Yard *	=	914.38348 cm. [914.5]
„	=	0.91438348 M. [0.9]
1 Pole (5.5 yds.)	=	5.02911 M. [5.03]
1 Chain (22 yds. or 100 links)	=	20.11644 „ [20.12]
1 Furlong (220 yds.)	=	201.16437 „ [201.16]
1 Mile (1760 yds.)	=	1609.31493 „ [1609.3]
„ „	=	1.60931493 Km. [1.61]

* *Definition of the Yard.*—The yard is the length between two scratches at 62° F. marked on a bronze bar deposited with the Board of Trade.

TABLE III

1 Millimeter	=	0.03937 in. [0.04]
1 Centimeter	=	0.39371 „ [0.40]
1 Decimeter	=	3.93708 „ [4.0]
1 METER	=	3.2808992 ft. [3.3]
	=	1.0936331 yds. [1.1]
1 Decameter (10 meters)	=	10.93633 „ [10.9]
1 Hectometer (100 meters)	=	109.36331 „ [109.4]
1 Kilometer (1000 meters)	=	0.62138 miles [0.62]
1 Myriameter (10 kilometers)	=	6.21382 „ [6.2]

In order to convey a clearer picture of what the lengths given above actually represent, it will be as well to compare them with lengths and distances which everyone is more or less acquainted.

Millimeter.—The edge of a sixpence measures almost exactly 1 mm. The edges of a sovereign measure about 1.5 mm.

Centimeter.—A penny stamp is 2 cm. wide and 2.3 cm. long. The diameter of a penny is about 3.2 cm.

Decimeter.—An ordinary table fork is just about 2 dm. long.

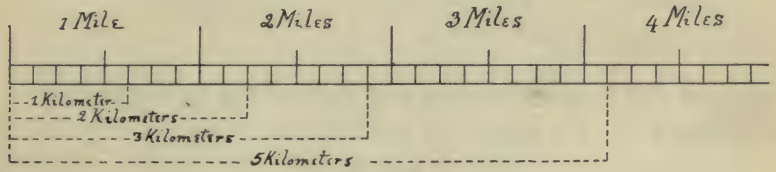


Fig. 3.

Meter.—Perhaps the best way to remember the length of the meter is that it is slightly longer than the yard, or the length is 3 feet, 3 inches and $\frac{1}{3}$ of an inch. This is easily remembered by bearing in mind 333.

Decameter.—The length of a cricket pitch (22 yards) is almost exactly 20 m. or 2 Dm.

Hectometer.—The length of a football field between the goal posts is nearly 1 Hm. and the width about $\frac{1}{2}$ Hm.[1]

Kilometer.—This is $\frac{5}{8}$ of a mile, and is represented diagrammatically in fig. 3. The distance be-

[1] This refers to the ordinary playing field and not to the international field.

tween London and Edinburgh (L. and N.W.R.) is 400 miles $= \frac{400 \times 8}{5} = 640$ km. The 4 mile cab radius used in London is 6.4 km. In Table IV a few more distances are given in miles and kilometers.

TABLE IV

London to Crewe,	158	miles	. . . . .	= 252 Km. 8 Hm.
„ Manchester,	183½	miles	(L.N.W.)	= 293 Km. 6 Hm.
„ „	203½	„	(G.N.R.)	= 325 Km. 6 Hm.
„ Herne Bay,	62¾	„	. . . .	= 100 Km. 4 Hm.
„ Dundee,	471	„	(L.N.W.)	= 953 Km. 6 Hm.
„ Dublin,	334	„	. . . .	= 534 Km. 4 Hm.
Liverpool to New York,	3025	„	. . . .	= 4840 Km.
„ Quebec,	2634	„	. . . .	= 4214 Km. 4 Hm.

A train travelling at the rate of 60 miles an hour would have a speed of 96 km. per hour.

Examples might be multiplied indefinitely, but as it is only a question of multiplying the number of miles by 8 and dividing the number so obtained by 5, there is no advantage in doing so.

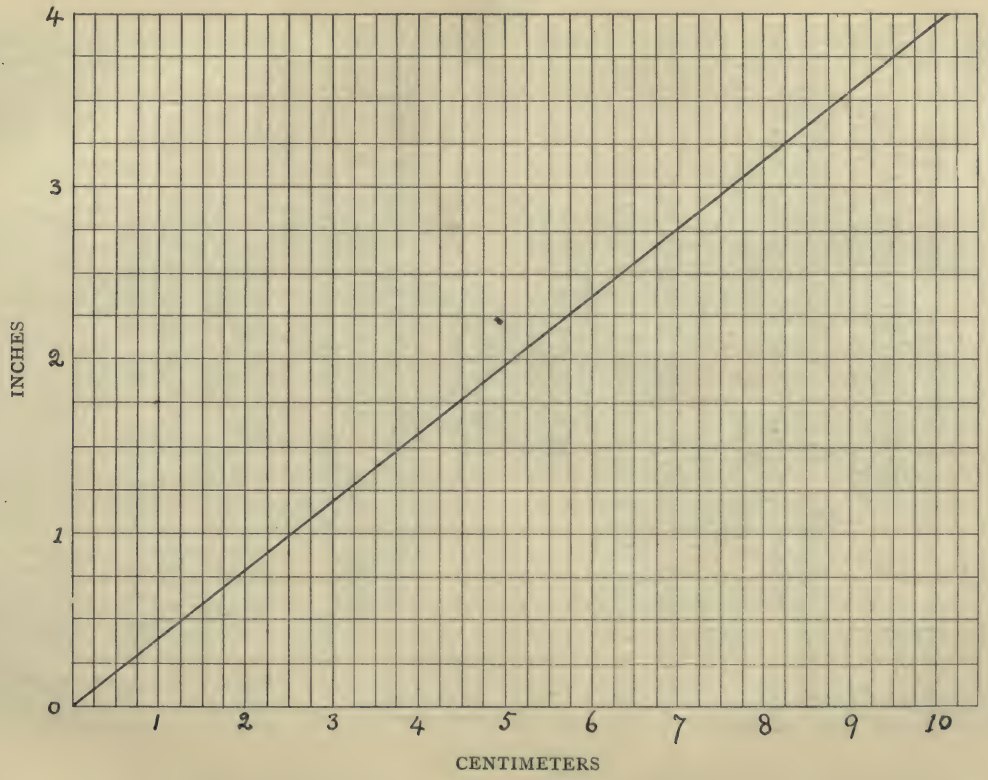
A few examples giving other linear measurements are, however, appended.

Example 1.—If the length of a path is 7 miles, 4 furlongs and 2 chains, how many kilometers would this be? By glancing at Table II there will be no difficulty in solving this question.

1 mile	= 1.61	Km. therefore	7 × 1.61	= 11.27 Km.
1 furlong	= 201.2	meters, „	4 × 201.2	= .8048 M.
1 chain	= 20.12	„ „	2 × 20.12	= .04024 M.
The answer is arrived at by addition.				12.11504

Or 12 kilometers, 1 hectometer, 1 decameter, 5

Fig. 4.



meters, 0 decimeters, and 4 centimeters. This latter is, however, rather a clumsy method of expressing the result. It is better to express it as kilometers and decimals of a kilometer, thus: 12.11504 km.

Or again, how many millimeters are there in 28 yards, 2 feet and 3 inches?

1 yard = 914.38348 cm., therefore 25 yards = $914.38348 \times 25 = 22858.587 \times 10 = 228585.87$ mm.

1 foot = 30.479449 cm., therefore 2 feet = $30.479449 \times 2 = 60.958898$, which multiplied by 10 = 609.58898 mm.

1 inch = 25.39954 mm., therefore 3 inches = $25.39954 \times 3 = 76.19762$ mm. The result is obtained by adding all these numbers together.

228585.87
609.58898
76.19762

229271.65660 mm.

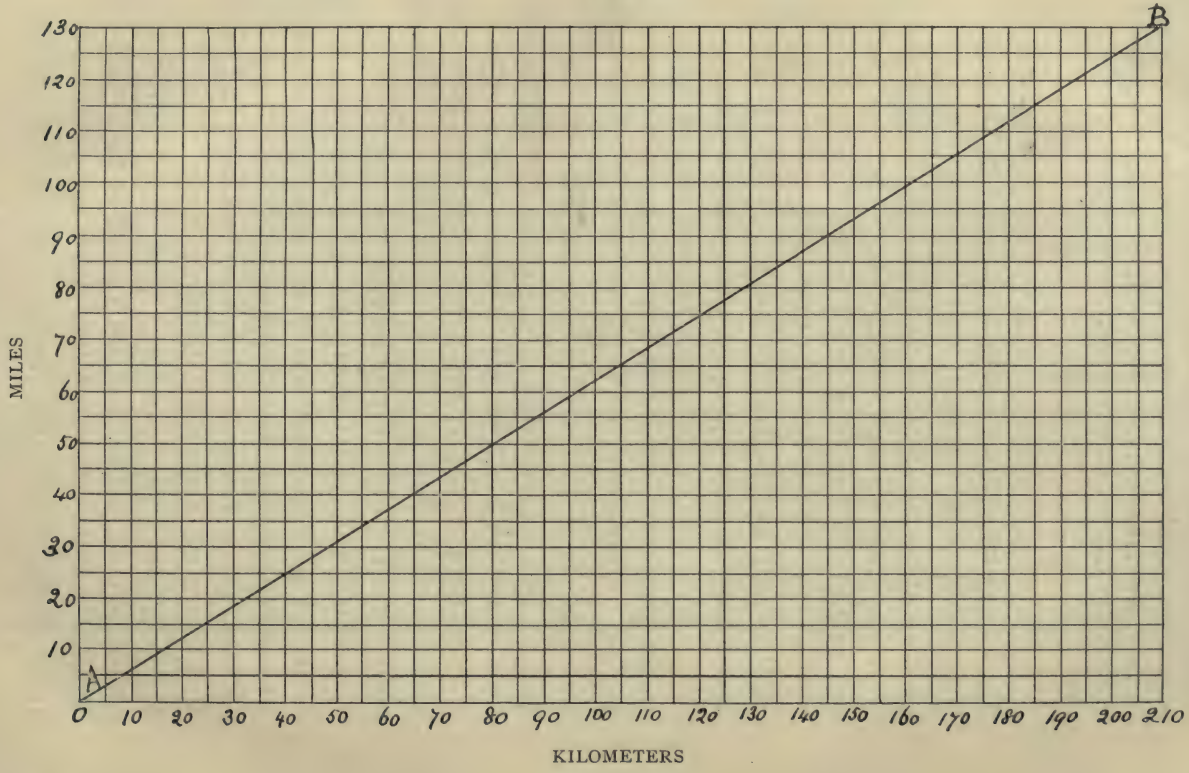
Of course, in actual practice, it is not at all necessary to work to so many decimal places, and thus consequently the arithmetic is considerably shortened.

The curve, fig. 4, is a very ready method for finding the number of inches which correspond to a given number of centimeters. It is plotted along the base line (*abscissa*) in centimeters, and up the perpendicular (co-ordinate) in inches.

Fig. 5 gives the comparison between miles and kilometers.

In order to read the curves, let us examine, for example, fig. 5 (miles and kilometers), and suppose that it is desired to know how many kilometers there are in 50 miles. We read up the perpen-

Fig. 5.


MILES
130
120
110
100
90
80
70
60
50
40
30
20
10
A
B
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210
KILOMETERS

dicular line or *co-ordinate*,[1] marked in miles until we come to the number 50, we then take a straight line at right angles to the perpendicular line across from this point until it cuts the diagonal line A B. A line is then dropped from this point until it cuts the base line or *abscissa* marked in kilometers. In the case under consideration, it will be found to cut the kilometer line at the point marked 80—that is, a distance of 50 miles is equal to 80 kilometers.

Each square, it will be noticed, is equal to 5 kilometers, and also to 5 miles, depending upon whether the base or perpendicular line is read. Therefore, if the line which is dropped from the line A B falls in the centre of a square, *e.g.*, between 20 and 25, this would be 22.5 kilometers. It will thus be found that 20 miles is equal to 32.5 kilometers. All the succeeding curves which are given are read in an exactly similar manner.

A word of explanation should also be here given about Table V. This is marked in inches and centimeters. The numbers 10, 20, 30, etc., on the left-hand side, and divided from the interior of the table by a line, are inches. The numbers 1, 2, 3, etc., along the top line, and likewise divided off from the table, are also inches. Now, suppose it is desired to know how many centimeters there are in 4 inches.

[1] Co-ordinate means equality of rank or position, and abscissa means the cutting line. Therefore, where the co-ordinate is cut by the abscissa, we have a point at which the two magnitudes represented by the co-ordinate numbers and abscissa are equal, that is to say, taking the curve under discussion, where the miles and kilometers are equal.

TABLE V

Inches.	0	1	2	3	4	5	6	7	8	9
	Cm.	Cm.	Cm.	Cm.	Cm.	Cm.	Cm.	Cm.	Cm.	Cm.
0	—	2.54	5.08	7.62	10.16	12.7	15.24	17.78	20.32	22.86
10	25.4	27.94	30.48	33.02	35.56	38.1	40.64	43.18	45.72	48.26
20	50.8	53.34	55.88	58.42	60.96	63.5	66.04	68.58	71.12	73.66
30	76.2	78.74	81.28	83.82	86.36	88.9	91.44	93.98	96.52	99.06
40	101.6	104.14	106.68	109.22	111.76	114.3	116.84	119.38	121.92	124.46
50	127.0	129.54	132.08	134.62	137.16	139.7	142.24	144.78	147.32	149.86
60	152.4	154.94	157.48	160.02	162.56	165.1	167.64	170.18	172.72	175.26
70	177.8	180.34	182.88	185.42	187.96	190.5	193.04	195.58	198.12	200.96
80	203.2	205.74	208.28	210.82	213.36	215.9	218.44	220.98	223.52	226.06
90	228.6	231.14	233.68	236.22	238.76	241.3	243.84	246.38	248.92	251.46
100	254.0	256.54	259.08	261.62	264.16	266.7	269.24	271.78	274.32	276.85

Read the number directly below 4 on the top line, and this gives the number of centimeters, viz., 10.16. Or if it is wished to know the number of centimeters in 14 inches, then take the next line below, which in inches is marked on the perpendicular line as 10. But as 10 and 4 equal 14, we again read under 4, and so obtain 35.56 as the number of centimeters in 14 inches. Again, if 74 is required, read along the line 70 and beneath 4, and the number of centimeters in 74 inches is found to be 187.96.

MEASUREMENTS OF AREA, SQUARE MEASURE

FIG. 6 is a square decimeter—that is, a square, each side of which is one decimeter in length. It is divided up along each side into centimeters, and by joining each centimeter by means of parallel lines, the whole square decimeter becomes divided up into 100 equal parts or square centimeters. Hence we get

1 sq. dm. = 100 sq. cm.
1 sq. cm. = 100 sq. mm.

The right hand top corner square centimeter is marked off into millimeters along the edges, and by joining these we obtain 100 square millimeters. For small measurements the square decimeter is employed as the scale, but for all larger measurements the square meter is used. The above figure represents the one-hundredth part of a square meter, since if a square meter be divided into decimeters along each edge, and these be joined by parallel lines, each division so obtained will be 1 square decimeter, and the smaller squares which in fig. 6 are square millimeters, would represent square centimeters.

The unit of land measure is called the ARE, and is 100 square meters; just as the British unit is called the acre, and is 4,840 square yards.

TABLE VI

100 sq. mm.	= 1 sq. cm.
100 sq. cm. (10,000 sq. mm.) . .	= 1 sq. dm.
100 sq. dm. (10,000 sq. cm.) . .	= 1 sq. metre (Centiare)
100 sq. meters (10,000 sq. dm.) .	= 1 Are
100 Ares (10,000 sq. meters) . .	= 1 Hectare

In Tables VII and VIII the British and Metric square measures are compared.

TABLE VII

1 sq. inch	= 6.45137 sq. cm. (6.45)
1 sq. foot (144 sq. in.) . . .	= 9.28997 sq. dm. (9.3)
1 sq. yd. (9 sq. ft.)	= 0.8360972 sq. M. (0.84)
1 perch (30.25 sq. yds.) . .	= 25.29194 sq. M. (25.3)
1 rood (40 sq. perch.) . . .	= 10.11678 Ares (10.12)
1 acre (4840 sq. yds.) . . .	= 0.40467 Hectare (0.41)
1 sq. mile (640 acres) . . .	= 258.98945 Hectares (259)

TABLE VIII

1 sq. centimeter	= 0.1550 sq. in. (0.155)
1 sq. decimeter	= 15.5005 sq. in. (15.5)
1 sq. meter (Centiare) . . .	= 10.7643 sq. ft. (10.80)
,, ,, . . .	= 1.19603 sq. yd. (1.2)
Are	= 119.60333 sq. yds. (119.6)
Hectare	= 2.47114 acres (2.5)

Suppose it is required to find out the number of hectares contained in a field, the size of which is 3 acres, 1 rood, and 2 perches. We can arrive at the result very simply by taking out the corresponding quantities in Table VIII.

1 acre = 0.40467 hectare; multiplying this by 3, we obtain 1.201401 hectare.

1 rood = 10.11678 ares, or, as 100 ares are equal to 1 hectare, if we divide by 100, we obtain 0·1011678 hectare.

Finally, 1 perch = 25.29194 square meters, but

100 square meters equals 1 are, therefore divide by 100, when we obtain 0.2529194, and to bring this to hectares again divide by 100, which gives 0.002529194, and as there are 2 perches, this

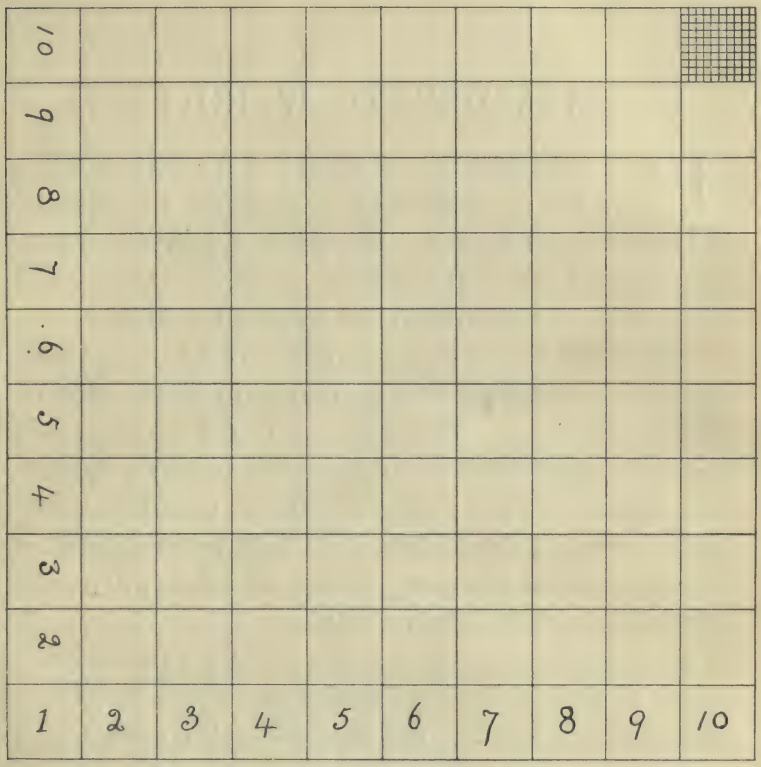


Fig. 6.

number must be multiplied by 2, thus: 0.005058388 hectare. The answer is obtained by adding these three numbers together.

1.2014010
0.1011678
0.0050584

1.3076272 Hectare.

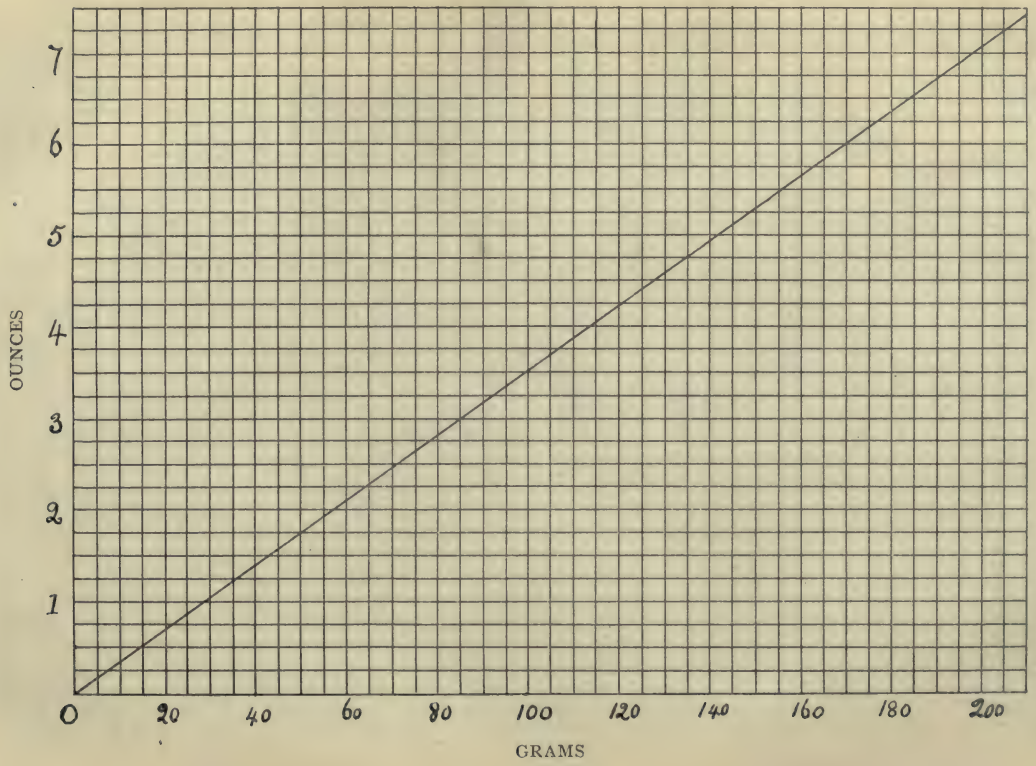
MEASURES OF WEIGHT

THE measurement of weight is directly derived from the measurement of capacity, the unit of weight being the GRAM. The gram is defined as THE WEIGHT OF 1 CUBIC CENTIMETER OF DISTILLED WATER, MEASURED AT A TEMPERATURE OF 4° CENTIGRADE.

Water has the peculiar property of having a point of *maximum density* at a temperature above that of its freezing point. Whenever a liquid is cooled, it contracts, and thus as it becomes cooler occupies less space. The point at which liquids—*except water*—occupy least space is at that temperature at which the least lowering of temperature will cause them to freeze or become solid.

Thus suppose a vessel holds exactly 1 cubic centimeter of benzene at 50° Centigrade, if the temperature is lowered to 25°, the benzene will contract, and will therefore no longer fill the vessel, but the weight will be the same. If it is filled up to the mark at this temperature it will obviously weigh more than it did at the temperature of 50°, because in order to keep it full more benzene has had to be added. Now, if further cooled, the contraction will go on and will continue until the freezing point of the benzene is reached, after which, of course, it will become solid. Therefore 1 cubic centimeter of

Fig. 7.



liquid benzene will weigh most at the temperature at which benzene solidifies.

Let us now take the case of water, and suppose a vessel of exactly 1 cubic centimeter capacity to be filled with water at a temperature of 4° Centigrade,

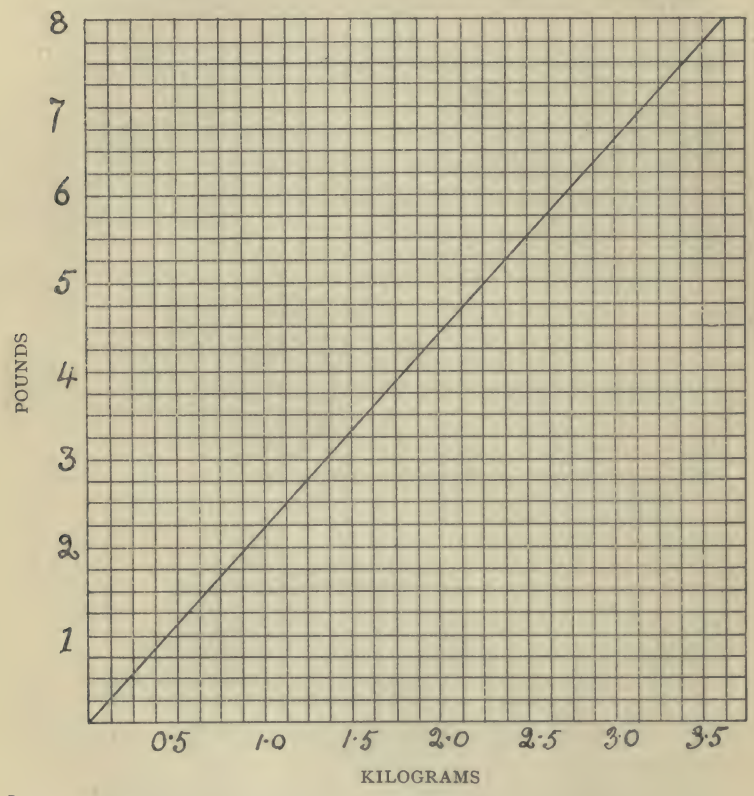


Fig. 8.

this bulk of water weighs exactly 1 GRAM—that is to say, a piece of metal was originally prepared which had exactly the same weight as this quantity of water at the temperature of 4° Centigrade, and this weight was called the GRAM.

Now heat the water so that the temperature is raised, say to 8° Centigrade, it will be found that the water expands, and that a portion flows over. Obviously, therefore, the water left in the vessel can no longer weigh 1 gram, although the volume is still 1 cubic centimeter.

Again, cool to 4° Centigrade, and fill exactly to the top, as at first, with water; the water will weigh 1 gram as before. Now cool to 0°, and it will be found that the water will expand and a portion will flow over (just as it did when it was heated from 4° to 8°). The water remaining in the vessel will exactly fill it, and will therefore have a volume of 1 cubic centimeter, but it will weigh less than 1 gram. By experiment it has been proved that at no other temperature than 4° Centigrade will 1 cubic centimeter of water weigh 1 gram. Therefore at this temperature water is *densest*, or, in other words, a given bulk of water will weigh more at a temperature of 4° Centigrade than at any other temperature, and therefore it is said that at this temperature water is at its MAXIMUM DENSITY, or 4° Centigrade is the *temperature of maximum density of water*.

TABLE IX

$\frac{1}{10}$ gram	0.1 gram	= 1 decigram (dg.)
$\frac{1}{100}$ „	0.01 „	= 1 centigram (1 cg.)
$\frac{1}{1000}$ „	0.001 „	= 1 milligram (1 mg.)
1 GRAM		
10 grams	... ...	= 1 decagram (Dg.)
100 „	... ...	= 1 hectogram (Hg.)
1000 „	... ...	= 1 kilogram (kg.)
10 Kilograms	... ...	= 1 myriagram
100 „	... ...	= 1 quintal
1000 „	... ...	= 1 tonne or millier

The term myriagram is very rarely used, and one more often talks of 100 kilograms than of 1 quintal, although this latter name is employed fairly often.

TABLE X

Metric Weights to Avoirdupois Weight

1 Milligram	=	0.01543 grain (0.0154)
1 Centigram	=	0.15432 „ (0.154)
1 Decigram	=	1.54324 „ (1.54)
1 Gram	=	15.43235 „ (15.4)
1 Decagram	=	5.64383 drams (5.6)
1 Hectogram	=	3.52739 ounces (3.53)
1 Kilogram	=	2.204621 pounds (2.2)
1 Myriagram (10 kilos.)	=	22.04621 „ (22.05)
1 Quintal	=	1.96841 cwt. (2.0)
1 Tonne or Millier	=	0.98421 ton (0.98)

TABLE XI

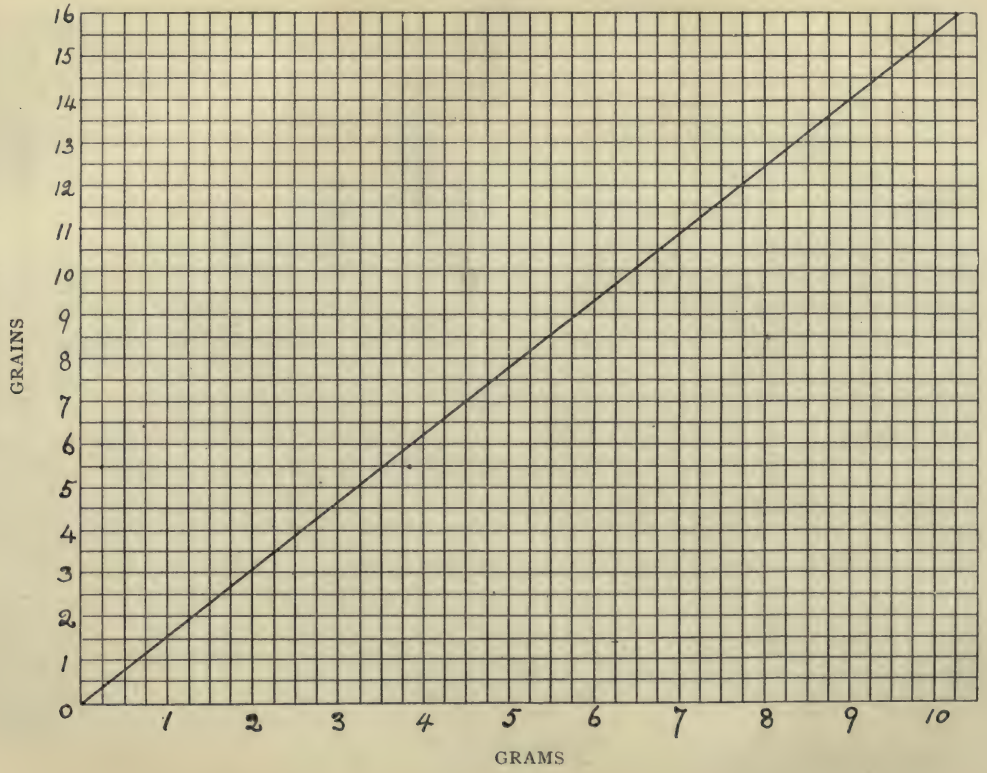
Avoirdupois Weight to Metric Weight

1 Grain	=	64.79895 milligrams (64.8)
1 Dram	=	1.77185 grams (1.78)
1 Ounce (16 dr.)	=	28.34954 „ (28.35)
1 Pound (16 oz.)*	=	453.5926 „ (453.6)
1 Stone (14 lb.)	=	6.3503 kilograms (6.35)
1 Quarter (28 lb.)	=	12.7006 „ (12.7)
1 Hundredweight (112 lb.)	=	50.8024 „ (50.8)
	=	0.50802 quintal (0.5)
1 Ton (20 cwt., 2240 lb.)	=	1016.05 kilo 1.01605 tonne (1.02)
1 Ton (2000 lb.—short ton)	=	907.1852 kilo 0.907185 tonne

* *Definition of the Pound.*—The pound is the weight of a piece of platinum weighed in vacuo at the temperature of 0° C., which is deposited with the Board of Trade.

The comparisons between TROY WEIGHT and Apothecaries' Weight will be found on p. 73.

Fig. 9.



Figs. 7, 8 and 9 are curves for finding the number of grams corresponding to ounces, pounds to kilograms, and for the use of pharmaceutical chemists grains against grams. The method of using the curves is explained on p. 26.

MEASURES OF VOLUME

THE unit of volume is the LITER, and is the volume of a cube, all the sides of which measure 1 decimeter. On p. 33 fig. 6 represents a square decimeter, that is, a square all the sides of which measure 1 decimeter, and which contains 100 square centimeters.

In fig. 10 A is a cubic centimeter (one-half the actual size); if ten of these are placed together a row 1 centimeter long and 1 centimeter across, and also 1 centimeter deep is obtained. If we place ten of these rows together a square results, each side of which is 1 decimeter long, and contains 100 of the cubes A. By now superposing nine more of these squares on the one already made, we obtain figure D, which is a cubic decimeter, since it is 1 decimeter long, 1 decimeter broad, and 1 decimeter deep. It is also obvious that it contains 1,000 cubic centimeters, because it is made by piling up ten squares on the top of each other, and each square contains 100 cubic centimeters, *i.e.*, $10 \times 100 = 1{,}000$. We thus get:

TABLE XII

100,000	Cubic Millimeters	...	= 1 liter
1,000	„ Centimeters	...	= 1 „
100	„ „	... ...	= 1 deciliter ($\frac{1}{10}$ liter), (dl.)
10	„ „	... ...	= 1 centiliter ($\frac{1}{100}$ liter), (cl.)
1	„ „	... ...	= 1 milliliter ($\frac{1}{1000}$ liter), (ml.)
LITER			
10 Liters	... ...		= 1 decaliter (Dl.)
100 „	... ...		= 1 hectoliter (Hl.)
1,000 „	... ...		= 1 kiloliter (Kl.)

TABLE XIII

Metric and British Equivalents of Capacity

1 Centiliter	= 0.6103 cub. in. (0.6)
1 „	= 0.0704 gill (0.07)
1 Deciliter	= 0.1761 pint (0.2)
LITER	= 1.7608 pints (1.8)
1 Decaliter	= 2.201 gallons (2.2)
1 Hectoliter	= 22.0097 „ (22.01)
1 „	= 2.7512 bushels (2.75)
1 Kiloliter	= 27.5121 „ (27.5)
1 „	= 3.439 quarters (3.44)

TABLE XIV

British and Metric Equivalents

1 Gill	= 1.4198 dl. (1.42)
1 Pint (4 gills)	= 0.56793 l. (0.57)
1 Quart (2 pints)	= 1.13586 l. (1.14)
1 Gallon (4 quarts) *	= 4.54346 l. (4.5)
1 Peck (2 gallons)	= 9.08692 l. (9.10)
1 Bushel (8 gallons)	= 3.63477 Dl. (3.6)
1 Sack (3 bushels)	= 1.0904 Hl. (1.1)
1 Quarter (8 bushels)	= 2.90781 Hl. (3.0)
1 Chaldron (12 sacks, 36 bushels)	= 13.0852 „ (13.1)

* *Definition of the Gallon.*—The gallon contains 10 lb. weight of distilled water at the temperature of 62° F., the barometer being at 30 inches. The weight of a cubic inch of water is 252.286 grains.

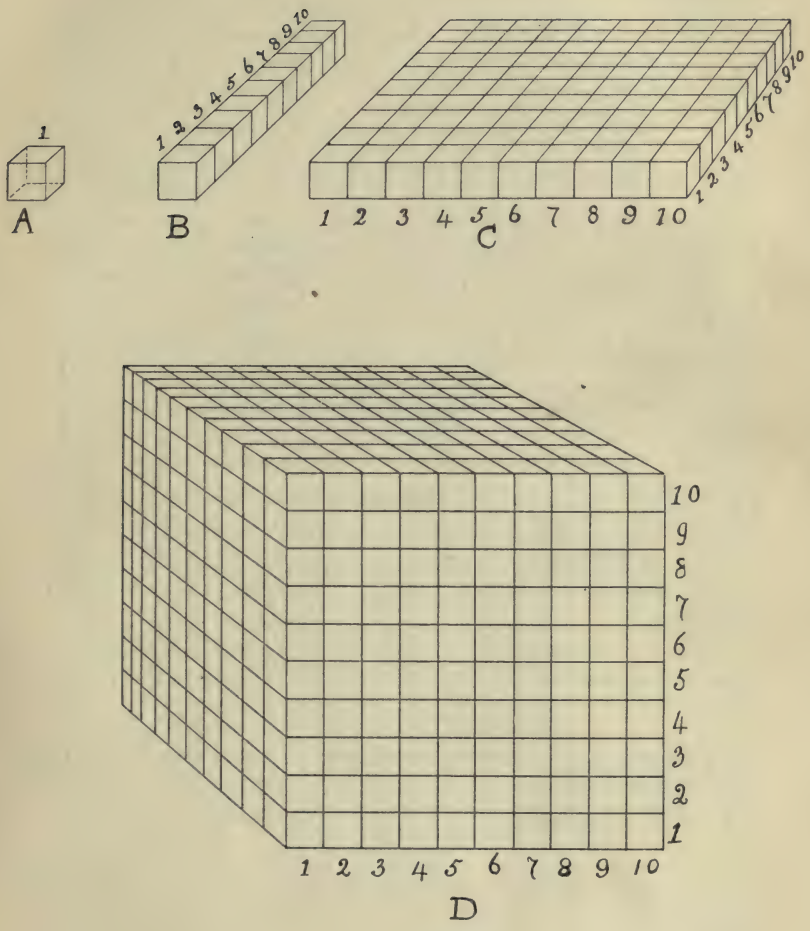


Fig. 10.

TABLE XV

Solid Measure

Metric and British Measures

1 Cubic Centimeter	... ...	= 0.06113 c. in. (0.06)
1 „ Decimeter	... ...	= 61.0271 c. in. (61.0)
1 „ Meter or Stere	... ...	= 35.316581 c. ft. (35.3)
1 „ „ „	... ...	= 1.308021 c. yd. (1.3)
1 „ „ „	... ...	= 0.882914[1] (shipping ton) of merchandise (0.9)
1 „ „ „	... ...	= 0.84087[1] (shipping ton of timber) (0.841)
1 „ „ „	... ...	= 1.09045 (ton displacement of a ship) (1.1)[2]

TABLE XVI

British and Metric Measures

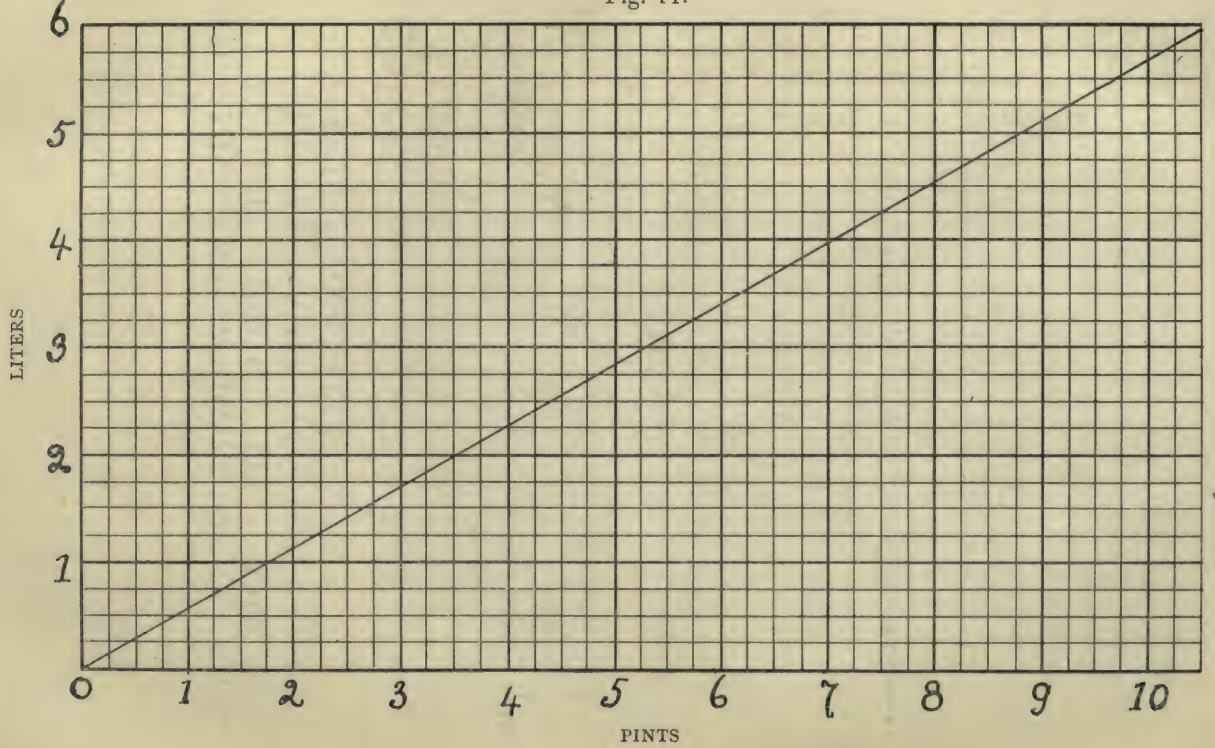
1 cubic inch	= 16.386176 c.c. (16.4)
1 „ foot (1,728 c. in.)	= 28.31531 c.dm. (28.3)
1 „ „ „	= 0.02832 C.M. (0.03)
1 „ yard (27 c. ft.)	= 0.7645134 C.M. (0.76)
1 shipping ton	= 1.1326 C.M. (1.13)
1 „ of timber	= 1.1892 C.M. (1.2)
1 ton displacement	= 0.99125 C.M. (1.0)

---

[1] The shipping ton for merchandise is 40 cubic feet, but is 42 cubic feet for timber.

[2] The ton displacement of a ship = 35 cubic feet.

Fig. 11.



TO FIND THE WEIGHT OF A SUBSTANCE FROM ITS SPECIFIC GRAVITY, AND TO DETERMINE SPECIFIC GRAVITIES.

SINCE 1 cubic centimeter of water weighs 1 gram, and 1 cubic decimeter of water weighs 1 kilogram (1,000 grams), 1 cubic meter of water will weigh 1,000 kilograms, this weight being the metric ton. In fact, the metric ton is defined as being the weight of 1 cubic meter of water at its maximum density (*see* p. 37).

This is very convenient to the engineer and builder, and to anyone who requires to know the weight of materials. If the engineer knows the specific gravity of a substance (and tables of specific gravities are easily obtainable),[1] then he knows that one cubic meter of that material weighs its specific gravity in metric tons, and 1 cubic centimeter of the material weighs its specific gravity in grams. For example, the specific gravity of lead is 11·36; therefore 1 cubic centimeter of lead weighs 11·36 grams, and 1 cubic meter weighs 11·36 metric tons or 11,360 kilograms.

The SPECIFIC GRAVITY of a substance is the number obtained when the mass or weight of a substance is

[1] Some specific gravities are given on p. 83.

divided by the mass or weight of its own volume of water. We thus get

$$Sp.\ Gr. = \frac{\text{Weight of any volume of the substance}}{\text{Weight of an equal volume of water}}$$

If, for example, we take a substance the volume of which is 1 cubic centimeter, then the specific gravity would be

$$Sp.\ Gr. = \frac{\text{Weight of 1 c.c. of substance}}{\text{Weight of 1 c.c. of water}}$$

In scientific work it is more usual to employ the term DENSITY, instead of specific gravity. Now the density of a substance is the mass or weight of a substance divided by its volume. The distinction really is that the specific gravity is the density of a substance divided by the density of water.

$$Sp.\ Gr. = \frac{\text{Density of substance}}{\text{Density of water}}$$

And the density of the substance is:

$$D = \frac{\text{Mass}}{\text{Volume}}$$

METHODS FOR OBTAINING SPECIFIC GRAVITIES.

The specific gravity of a substance which admits of easy measurement, such as a cube, oblong, or other regular piece of metal, wood or glass, the edges of which are parallel, is very readily obtained by measuring the *length*, *breadth*, and *depth*, multiplying these numbers together, and so obtaining its volume in cubic centimeters.

Now as a substance will displace its own volume

of water, and 1 cubic centimeter of water weighs 1 gram,[1] we can take the number of cubic centimeters, representing the volume of the substance as being equivalent to so many grams of water.

The substance is then weighed, and the specific gravity is found by dividing its weight in grams by the volume in cubic centimeters, which, as already stated, may be looked upon as being so many grams.

For example, the sides of a cube of aluminium were found to measure 2 centimeters. Therefore the volume is $2 \times 2 \times 2 = 8$ centimeters. The weight was found to be 20 grams, consequently the specific gravity is 2·5 (seeing that 1 centimeter of water weighs 1 gram),

$$\frac{20}{8} = 2.5$$

For a substance which does not admit of easy measurement, such as a glass-stopper or an irregular piece of metal, a glass vessel graduated in cubic centimeters and tenths of cubic centimeters may be partially filled with water, the height of the water carefully noted, the article weighed and then carefully dropped into the water so as not to splash any of the water out, or to fracture the glass vessel. The article displaces its own volume of water, therefore the water in the vessel takes up more room, and the increase in volume of the water is read off on the

[1] 1 c.c. of water only weighs exactly 1 gram at the temperature of 4° (*see* p. 37); but the difference for ordinary purposes is so slight that no notice need be taken of it except for very accurate determinations. In the other methods to be described this error is eliminated.

graduation. The specific gravity is then found by dividing this volume into the weight which has already been ascertained.

Another method is to weigh the solid, suspended by a piece of cotton, from the arm of a balance, and then to place a beaker of water below it, so that the substance is now suspended in water. As before, the solid will displace its own volume of water, and will therefore weigh less by the amount of water which it displaces. The specific gravity is found by dividing the difference in weight obtained when the substance is weighed in water, into the weight of the substance in air. Thus, if we call the weight of the substance in air W, and its weight in water w, we find the specific gravity by

$$\frac{W}{W-w} = Sp.\ Gr.$$

In using a balance the weights should always be placed on the right-hand pan, and the substance to be weighed upon the left. It may be asked how are you going to weigh a substance suspended from the arm of a balance by a piece of thread, first in air then in water, because the pan of the balance will get in the way? The difficulty is got over by having a little bridge which can be placed over the pan, as illustrated in fig. 12. Such a bridge can readily be made by bending a piece of sheet-iron twice at right angles, so that it forms a bridge over the balance pan, at such a height that the pan can move freely. Balances which are to be used for accurate work always have an arrangement to prevent them continually swinging; by changing over the handle, A, they can be caused to swing or remain at rest.

When weights are being put on or taken off, or a substance is being removed, the balance is always kept at rest.

Relative Density or Specific Gravity of Liquids.— This is very easily found by using a measuring vessel called a *burette*, which is illustrated in fig. 13. It consists of a glass tube fitted at one end with a

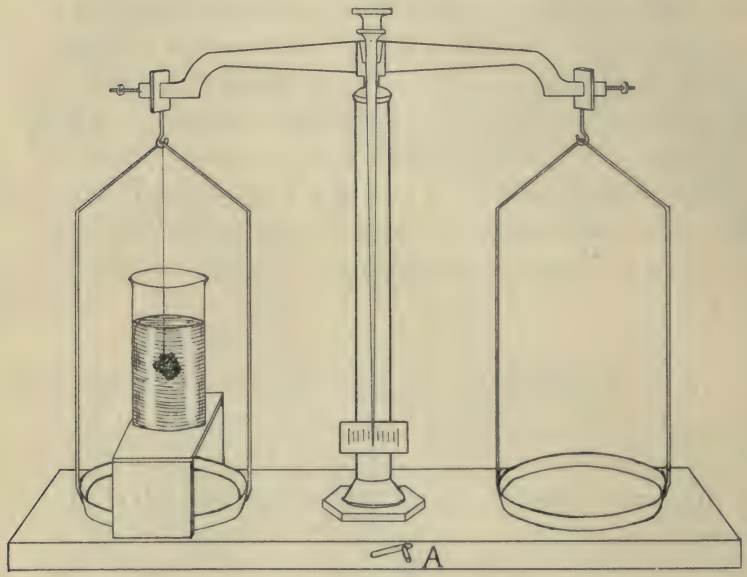


Fig. 12.

tap, and graduated in cubic centimeters and tenths of cubic centimeters. As a rule the burette is graduated to hold 50 c.c. of a liquid. If the burette is first filled with water, and 10 c.c. of the water run into a small glass vessel which has been carefully weighed, then the weight of this 10 c.c. of water can be accurately determined by weighing again and subtracting the weight of the glass vessel from the second weight obtained. It will, perhaps, be said,

"but 10 c.c. of water weigh 10 grams, since 1 c.c. weighs 1 gram." This is true if the temperature of the water is 4° C., but it was explained on p. 37 that only at 4° C. does 1 c.c. of water weigh 1 gram, at all other temperatures it weighs slightly less.

In order now to determine the specific gravity or relative density of another liquid (relative to that of water taken as 1), the water is emptied out of the burette, which is then either carefully dried[1] or rinsed out with the liquid, *e.g.* methylated spirit, and then filled up with the liquid. Ten c.c. are then carefully run out into the weighed glass vessel, and then the vessel with the methylated spirit or other liquid is again carefully weighed. The relative density of the liquid is found by dividing the weight just found by the weight of 10 c.c. of water. Thus, for example, suppose that the 10 c.c. of water weighed 9.91 grams, and the 10 c.c. of the methylated spirit weighed 8.20, then the relative density of the methylated spirit is

$$\frac{8.20}{9.91} = 0.827$$

The relative density or specific gravity of a substance is therefore defined as *the number obtained by dividing the weight of a*

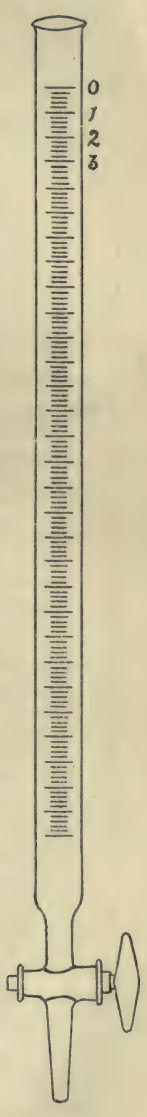


Fig. 13.

[1] When oil or other liquid which does not mix with water is used, then the burette must be dried after the water has been run out.

given volume of the substance by the weight of the same volume of water.

This, of course, applies equally to solids as to liquids.

It should be mentioned here that in reading the burette, it is necessary to keep the eye in direct line with the top of the level of the fluid contained in it. It will also be noticed that the fluid takes on a concave surface,[1] owing to the surface tension of the liquid, which causes it to cling to the sides of the burette, and has the appearance indicated in fig. 14. In reading the burette then, always take the reading from the bottom of this concave surface. Thus in the diagram, the bottom of the *meniscus* is shown to coincide with 10 c.c., therefore 10 c.c. will have run out when the bottom of the *meniscus* touches the 20 mark.

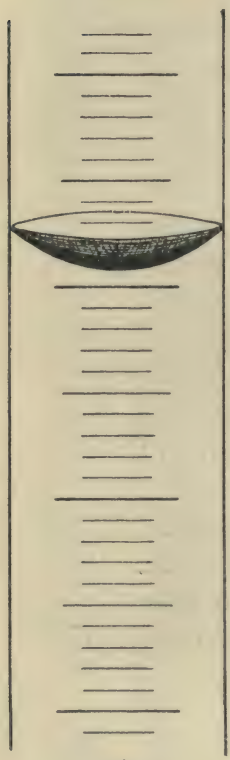


Fig. 14.

Another method for determining the specific gravity of liquids is to take a small flask with a mark on the neck. Weigh it empty and leave the weights on the balance. Now fill it to the mark with water and again weigh, the extra weights now required represent the weight of the water. Empty out the water, carefully dry the flask, and fill it with

[1] The peculiar form of surface is called the *meniscus*.

the liquid the specific gravity of which has to be determined, and again weigh it. The weight now obtained—less the weights necessary to counterpoise the flask—is the weight of the liquid. If we call the weight of the water W, and the weight of the liquid w, then the specific gravity is found by dividing W into w.

$$\frac{w}{W} = Sp.\ Gr.$$

Principle of Archimedes.—By weighing a substance, for example a piece of metal or glass, first in air, then in water, and then in another liquid, it is an easy matter to determine the specific gravity of that liquid. If we call the weight of the substance W, its weight in water w, and its weight in the other liquid w_1, then the specific gravity is found as follows:

$$\frac{W - w_1}{W - w}$$

It will be noticed that by this means we are simply dividing the weight of the water displaced by the substance, into the weight of the other liquid displaced by the same substance, the volumes of the water and of the other liquid are therefore the same.

Specific Gravity of Substances Lighter than Water.

In order to find the specific gravity of substances which are lighter than water, and therefore float upon its surface, it is necessary to weight them so that they sink below the surface, otherwise it would not be possible to ascertain the volume of water

displaced. The weight and volume of the sinker must first be found. In the first place the solid lighter than water, the specific gravity of which it is desired to find, is weighed; let us call this weight W. The sinker is then weighed in air; let this weight be w. It is now weighed in water, and this weight is called w_1. Finally the sinker is tied onto the substance, the specific gravity of which is required, and both are weighed in water, when the weight w_2 is obtained. We have therefore:

First weight of light solid in air	$= W$
Weight of sinker in air	$= w$
„ „ water	$= w_1$
„ „ and light solid in water	$= w_2$

Then weight of water displaced by solid and sinker is:

$$(W + w) - w$$

and the weight of water displaced by the sinker is:

$$w - w_1.$$

Therefore the weight of water displaced by the light solid is:

$$[(W + w) - w_2] - (w - w_1),$$

and the specific gravity is:

$$Sp.\ Gr. = \frac{W}{[(W - w) - w_2] - (w - w_1)}$$

and finally, by cancelling out the two w's, we obtain:

$$Sp.\ Gr. = \frac{W}{(W - w_2) + w_1}$$

Seeing that the two w's cancel, it is not necessary to know the weight of the sinker in air, therefore only three weighings are necessary.

Example.—A solid weighed 5.27 grams in air, when tied to the sinker and weighed in water, the weight of the solid and sinker was 7.45 grams. The sinker alone weighed 7.67 grams in water. Hence

$$\begin{aligned} W &= 5.27 \\ w_2 &= 7.45 \\ w_1 &= 7.67 \end{aligned}$$

Therefore the specific gravity of the solid is—

$$Sp.\ Gr. = \frac{5.27}{(5.27 - 7.45) + 7.67}$$

TEMPERATURE MEASUREMENTS

FOR measuring temperature there are, in this country, two scales employed, the FAHRENHEIT scale, in general use, and the CENTIGRADE scale, which is employed in science.

The Fahrenheit thermometer is named after its inventor, whereas the Centigrade thermometer is so named because, between the freezing point of water and its boiling point, the scale is divided into 100 parts or degrees (Latin *centum*, a hundred, and *gradus*, a degree). But on the Fahrenheit scale, the freezing point of water is marked as 32°, and the boiling point of water as 212°.

We have here again, as in the metric and other systems, a rational and an irrational form of measurement. At the time when Fahrenheit constructed his thermometer, very little was known about low temperatures, and he was of the opinion that the zero point should be at the lowest attainable temperature. Fahrenheit found that the lowest temperature which he could attain was that produced when he mixed ice and salt together, and he therefore placed his thermometer in this mixture, and called the point to which the mercury sank, zero or 0°. The thermometer was then placed in steam, and the point which the mercury then reached was marked as 212°, which was certainly a very arbitrary number to take.

The *Zero* point in the CENTIGRADE thermometer is the true freezing point of water, and is found by placing the thermometer in melting ice; the boiling point of water is found as in the Fahrenheit thermo-

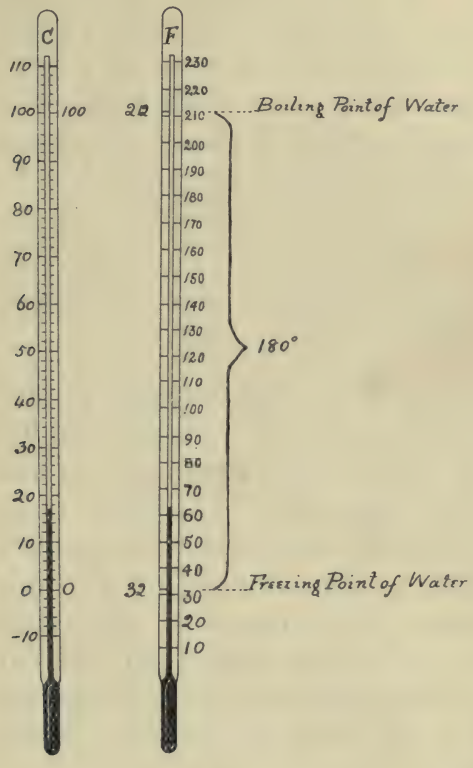


Fig. 15.

meter, by placing the thermometer in steam and marking off the point to which the mercury then rises. Between the freezing point and boiling point is then marked off in 100 parts, which although arbitrary, as of course all scales must be, is rational.

In introducing the metric system, it would certainly

be better to introduce the centesimal thermometer also, and thus avoid muddles and often errors.

For example, in electroplating it is often important to keep the plating-bath at a constant temperature, in copper deposition, for instance, about 90 to 100° Fahrenheit. Now if a practical plater were to say to a scientifically trained person, the bath is to be kept at 90°, the person would imagine he meant 90° Centigrade, which is nearly the temperature of boiling water, and would be 194° on the Fahrenheit scale.

Conversion of Fahrenheit and Centigrade Scales.

On examining fig. 15 it is seen that 180° Fahrenheit correspond to 100° Centigrade, and if we divide both sides by 20, then we get: 9° Fahrenheit correspond to 5° Centigrade. Therefore, 1° Fahrenheit corresponds to $\frac{5}{9}$° Centigrade (in decimals 0.55°), and $\frac{9}{5}$ Fahrenheit (1.8) corresponds to 1° Centigrade.

Centigrade to Fahrenheit.—The simplest way to convert Centigrade degrees to Fahrenheit is to multiply the number of degrees Centigrade by 1.8 and then to add 32 to the number so obtained. We thus obtain:

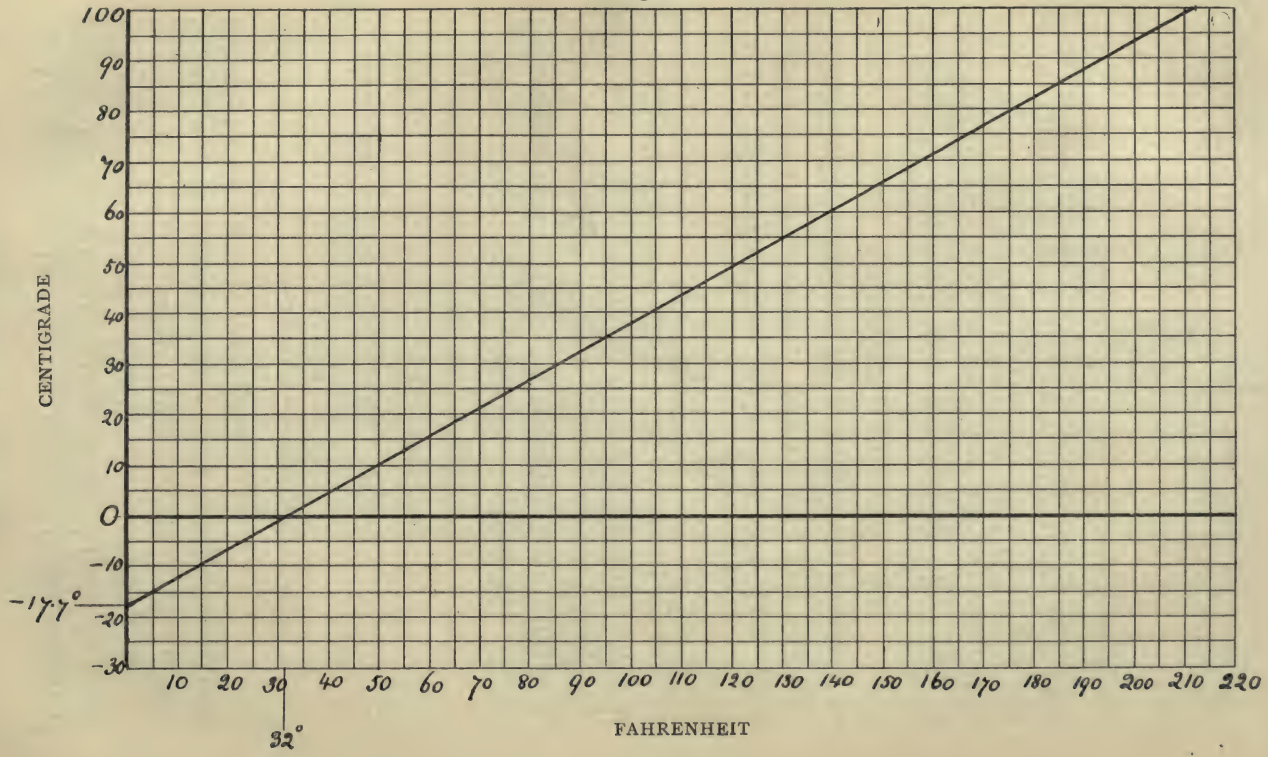
$$F = (C^\circ \times 1.8) + 32$$

Example.—The melting point of lead is 326° Centigrade; at what temperature Fahrenheit does it melt?

$$F = (326 \times 1.8) + 32 = 618.8^\circ F$$

When the temperature is below zero, then 32 is *not* added, but the number obtained on multiplying

Fig. 16.


100
90
80
70
60
50
40
30
20
10
0
-10
-17·7°
-20
-30
CENTIGRADE
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220
32°
FAHRENHEIT

by 1.8 is; if *less* than 32, subtracted from 32, but if *greater* than 32, then 32 is subtracted from it. And the final product has a — sign placed before it.

Example.—The temperature registered on the Centigrade thermometer is $-10°$; what temperature Fahrenheit does this represent?

$$-10 \times 1.8 = -18$$
$$32 - 18 = 14° F$$

Example.—The Centigrade temperature is -35.

$$-35 \times 1.8 = -63$$
$$63 - 32 = -31° F$$

Fahrenheit to Centigrade.—Since the degree Fahrenheit is only $\frac{5}{9}$ or 0.55° of the degree Centigrade, we can obtain the degrees Centigrade which correspond to Fahrenheit by first subtracting 32, and then multiplying the number so obtained by 0.555.

$$C = (F - 32) \times 0.555$$

Or by using fractions which in this case give slightly greater accuracy. Subtract 32 and multiply the number so obtained by 5, and then divide by 9.

$$C = (F - 32) \times \tfrac{5}{9}$$

It may be objected that multiplying by 555 is rather tedious. This, however, is not the case; it is only necessary to multiply once, and then put the same figures down again, removing them one unit to the left, *e.g.*, 25×0.555.

$$\begin{array}{r} 125 \\ 125 \\ 125 \\ \hline 13.875 \end{array}$$

So that it is simply a case of multiplying once by 5, putting down the same figures again twice, and adding.

Example.—The temperature shown on a Fahrenheit thermometer is 81°; what does this correspond to on the Centigrade scale.

(1) By decimals:

$$81 - 32 = 59$$
$$59 \times 0.555 = 32.74^\circ C$$

(2) By fractions:

$$81 - 32 = 59$$
$$59 \times \tfrac{5}{9} = 32.8$$

Example.—Express 14° Fahrenheit in degrees Centigrade.

(1) By decimals:

$$14 - 32 = 18$$
$$18 \times 0.55 = 9.99$$

(2) By fractions:

$$14 - 32 = 18$$
$$18 \times \tfrac{5}{9} = 10$$

There is also another thermometer which is sometimes used abroad, the RÉAUMUR. In this thermometer the freezing point of water is marked as 0°, but between the freezing and boiling point is divided into 80 divisions, thus the boiling point of water is 80°.

To convert Réaumur to Fahrenheit, multiply the degrees Réaumur by 2.25, and add 32.

$$F = (2.25 \times R) + 32$$

To convert Réaumur to Centigrade, multiply the degrees Réaumur by 1.25.

$$C = 1.25 \times R$$

To convert Centigrade to Réaumur, multiply the degrees Centigrade by 0.8.

$$R = C \times 0.8$$

To convert Fahrenheit to Réaumur, subtract 32, and multiply the number so obtained by 0.444.

$$R = (F - 32) \times 0.444$$

The curve (fig. 16) shows the comparison between the Fahrenheit and Centigrade scale. Degrees Fahrenheit are marked along the base line, the perpendicular being divided off into degrees Centigrade up to 100°. If we desire to know how many degrees Centigrade are equivalent to 80° Fahrenheit, the number 80° is taken, and a straight line followed up until it intersects the curve line, then a line is run at right angles until it intersects the perpendicular line marked off in Centigrade degrees; this we find to be slightly less than 27; the actual calculated number is 26.7. The approximation is, however, sufficiently exact for all practical purposes.

MONEY

BY converting British money into decimals of a pound, we obtain a ready method for transforming British currency into foreign currency, and *vice versa.*

In decimalizing the pound sterling, it is simplest to remember that 2*s.* is the tenth part of a pound, and is therefore 0.1 of a pound; consequently 10*s.* is 0.5 of a pound. Now 0.05 is half of 0.1, and is therefore half of 2*s.*, so that 1*s.* is 0.05 of a pound, and 0.025 is 6*d.*

In the same way we find that 0.01 is one-tenth of 2*s.*, and is thus equal to 2.4 or $2\frac{2}{5}$ pence, which is almost, but not quite, $2\frac{1}{2}d.$ In the third place of decimals, 0.001 is practically 1 farthing (if there were 1,000 farthings in the pound instead of 960 it would be exactly 1 farthing). The decimals in the fourth place are fractions of a farthing, 0.0005 being almost half a farthing.

It should be noted that if there were exactly 1,000 farthings in the pound, there would be absolutely no difficulty in decimalizing English money, and in any new arrangement of the coinage (that is to say, if it were to be arranged on a decimal basis), it would be necessary to have the pound divided into 10, 100, and 1,000 parts. As a matter of fact, as already stated, the pound sterling contains only 960 farthings,

hence the difficulty of conversion. The difficulty is, however, more imaginary than real, because by taking out to four or five places of decimals we make the difference negligible. For example, the average exchange of the sovereign in Germany is 20.40 marks. Suppose, therefore, a piece of cloth cost 1.75 mark, how much would this cost in English money? Divide the price by the rate of exchange to four places of decimals, when we obtain

$$
\begin{array}{r}
20.40)\ 17500\ (0.0858 \\
16320 \\
\hline
=\ 11800 \\
10200 \\
\hline
=\ 1600
\end{array}
$$

That is 1*s.* 8¾*d.* nearly, or almost exactly 1*s.* 9*d.* The error is only a small fraction of 1 farthing, and would be eliminated in dealing with large quantities. For example, if instead of wanting to know the price of 1 meter in English money we wished to know how much 100 meters would cost, then it is better to work out to five places of decimals, and to multiply the number by 100, when we get 0.08578, which, when multiplied by 100, becomes 8.758, or £8 15*s.* 2*d.*

Conversely, if we have the price in English money to convert into foreign. To do this, multiply the rate of exchange by the decimals of £1 represented by the British price.

For example, the price of an article is 2*s.* 3*d.*, how much would that be in francs, when the rate of exchange is such that 25.15 francs equal £1.

2*s.* 3*d.* is 0.1125 of a pound, therefore we obtain

the price in francs by multiplying this decimal by the rate of exchange, thus:

$$0.1125 \times 25.15 = 2.294 \text{ francs}$$

TABLE OF ENGLISH MONEY IN DECIMALS OF A POUND STERLING

$\frac{1}{4}d.$	=	0.00104	11*d.*	=	0.04583
$\frac{1}{2}d.$	=	0.00208	1*s.*	=	0.05000
$\frac{3}{4}d.$	=	0.00312	1*s.* 3*d.*	=	0.06250
1*d.*	=	0.00417	1*s.* 6*d.*	=	0.07500
2*d.*	=	0.00834	2*s.*	=	0.10000
$2\frac{1}{2}d.$	=	0.01042	2*s.* 6*d.*	=	0.12500
3*d.*	=	0.01250	3*s.*	=	0.15000
4*d.*	=	0.01667	3*s.* 6*d.*	=	0.17500
5*d.*	=	0.02083	4*s.*	=	0.20000
6*d.*	=	0.02500	4*s.* 6*d.*	=	0.22500
7*d.*	=	0.02917	5*s.*	=	0.25000
8*d.*	=	0.03333	10*s.*	=	0.50000
9*d.*	=	0.03750	15*s.*	=	0.75000
10*d.*	=	0.04166			

For purposes of rough calculation the figure in the third decimal place may be called farthings, each unit in the second place is practically equal to $2\frac{1}{2}d.$, and each unit in the first place is exactly equal to 2*s.*

If it is desired to work back further than five places of decimals, then divide 0·05, which is 1*s.*, by 12 to as many places of decimals as may be desired, when one obtains 0.0041666. In this way we obtain the decimal of a pound which 1*d.* represents.

It does not, of course, matter whether we wish to convert francs, marks, roubles, or any other coinage, provided the bank rate is known. For ordinary calculations the appended rates will be found sufficiently accurate, but for commercial trans-

actions it is necessary to employ the exchange rate ruling at the time.

APPROXIMATE RATES OF EXCHANGE

France	25.20 francs and centimes per £.
Germany	20.40 marks and pfennige „
Austria	24.15 kronen and heller „
Russia	10.195 roubles and kopecks (1 rouble is slightly more than 25*d.*).
Holland	12.09 florins and kreuzers per £.
Italy	26.05 lire and centisimi „
India	1 rupee = 15.375 pence.
Spain	29.25 pesetas and centesimos per £.
America	4.86 dollars and cents per £.
Japan	1 yen is about 3*s.* 10*d.*
Egypt	100 piastre piece = £1. 0*s.* 3½*d.*
Turkey	100 piastre piece = £0. 18*s.* 1*d.*

The calculations for money exchange are not very troublesome, and they would be still simpler if we were to divide our coinage up on the decimal system. In order to do this, we could retain the florin as it is the *tenth part* of one pound, and the florin would be divided into one hundred parts, each of which would be the *thousandth part* of the pound and might be called *mils*, or the name farthing might be retained. The shilling would be retained as 0.05 of the pound, the sixpence would also be kept and would be 0.025 of the pound; it would, however, no longer represent 24 farthings, but 25 mils (or farthings, if these were made to represent mils); half of the sixpence or 25 mils would be about 2½*d.*, so we should have a coin to represent this, and so on. We can, however, manage in the meantime with our system of coinage if only our *systems* of weights and measures are placed on a sound footing.

It becomes a complicated problem if it is required to know the price sterling of a certain number of yards when the data given to us is in meters and francs.

In order to show the complexity of the existing system two examples are given here.

Example I.—If 1.0 meter of cloth cost 6.55 francs, what is that per yard in British money, the pound being worth 25.22 francs, the meter equal to 39·37 inches?

If 39.37 inches cost 6.55 francs, 1 inch would cost $\frac{7\cdot5}{39\cdot37}$ and therefore 36 inches would cost $\frac{6.55 \times 36}{39\cdot37}$ francs.

If 25.22 francs are equivalent to £1 (240 pence), 1 franc is equivalent to $\frac{240}{25.20}$.

Therefore 36 inches would cost $\frac{6.55 \times 36 \times 240}{39\cdot37 \times 25.20}$ = 57 pence.

Example II.—If 1 yard of cloth cost 5*s.* 8*d.*, how much is that per meter in Russian money,[1] the pound being equal to 10.195 roubles, and the meter equal to 39.37 inches.

If 36 inches cost 5*s.* 8*d.*, 1 inch costs $\frac{68}{36}$ pence, and 39.37 inches cost $\frac{68 \times 39.37}{36}$.

[1] As a matter of fact the metric system is not compulsory in Russia, but the metric system is used to a considerable extent. There is little doubt but that Russia will be one of the nations to follow if Great Britain adopts the metric system.

If 20*s.* (240 pence) are worth 10.195 roubles, 1*d.* is worth $\frac{10.195}{240}$; and the number of pence in the fraction above is $\frac{68 \times 39.37 \times 10.195}{36 \times 240} = 3.160$ roubles.

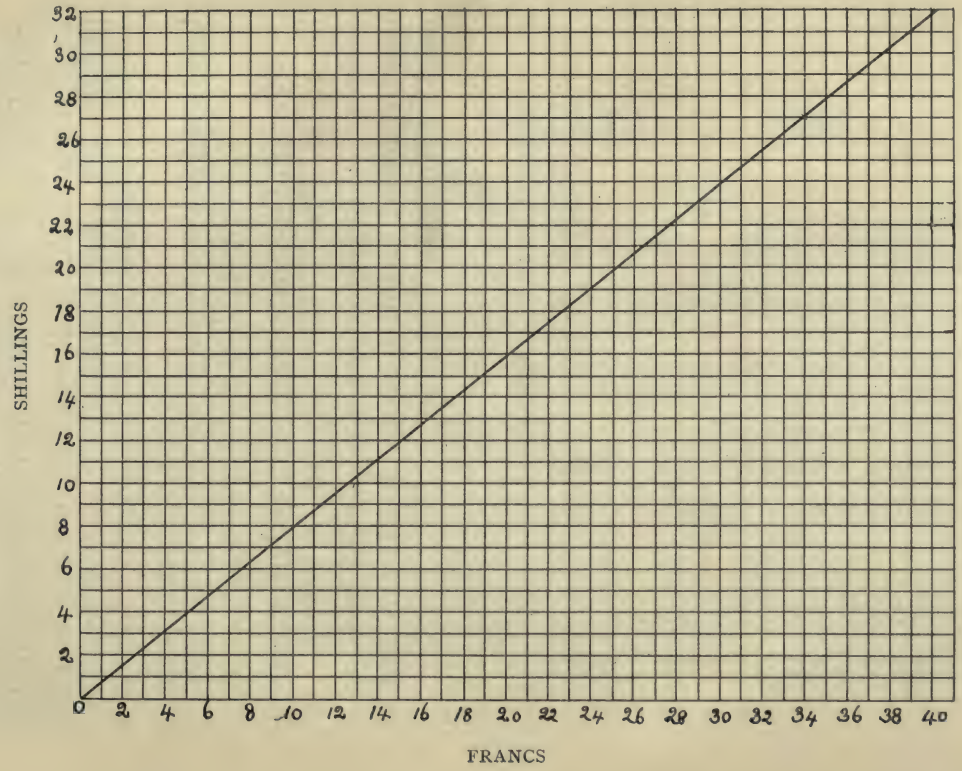
Conversion of French money into currency of Great Britain in connection with the Exchange of Money Orders.

For the conversion of money orders the exchange is always the same, therefore a table of fixed values can be employed. Fractions of pennies are never recognized by banks when changing money orders. Thus, if the amount was £3 1*s.* 3⅓*d.*, the bank would only pay £3 1*s.* 3*d.*

French Money (centimes).	English Equivalent (pence).	French Money (centimes).	English Equivalent (pence).
1	0.1	20	1.9
2	0.2	30	2.9
3	0.3	40	3.8
4	0.4	50	4.8
5	0.5	60	5.7
6	0.6	70	6.7
7	0.7	80	7.6
8	0.8	90	8.6
9	0.9	100	9.5
10	1.0	1000	95.0

To find the British equivalent for odd numbers, for example, for 23 centimes, take the number opposite 20, which is 1.9, and add it to the number opposite 3, which is 0.3, thus 1.9 + 0.3 = 2.2. Pro-

Fig. 17.


SHILLINGS
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
FRANCS

ceed in the same way to find any number up to 100. For instance, 85 centimes is $7.6 + 0.5 = 8.1$ pence.

By means of the curve, fig. 17, there is no difficulty in finding out how many francs correspond to a given number of shillings. The method for reading curves is given on p. 26.

Canadian Money to be paid for Money Orders on the United Kingdom.

Although Canadian money is not arranged according to the French Metric System, a table for the exchange of money orders is appended here, as it may be found useful to many, and it can also be used for American exchange.

s.	*d.*	$	*c.*	£	*s.*	*d.*	$	*c.*
	1	0	02		14	0	3	41
	2	0	04		16	0	3	90
	10	0	20		18	0	4	38
	11	0	22	1	0	0	4	87
1	0	0	24	1	10	0	7	31
2	0	0	49	1	15	0	8	52
3	0	0	73	2	0	0	9	74
4	0	0	97	3	0	0	14	61
5	0	1	22	4	0	0	19	48
6	0	1	46	5	0	0	24	35
7	0	1	71	6	0	0	29	22
8	0	1	95	7	0	0	34	09
9	0	2	19	8	0	0	38	96
10	0	2	44	9	0	0	43	83
12	0	2	92	10	0	0	48	70

Supposing that it is required to know the exchange for 2*s.* 4*d.* By an examination of the table we find that 1*d.* is equivalent to 0.02 of a dollar, or 2 cents, therefore 4*d.* is equivalent to 0.08 of a

dollar, or 8 cents, and 2*s.* is equivalent to 0.49 cents, therefore by addition 0.08 + 0.49, we find the equivalent of 2*s.* 4*d.* to be 0.57—that is 57 cents, or slightly more than half a dollar, which, of course, is 50 cents.

Examples.—I. For remittance to the United Kingdom of the sum of £5 9*s.*, the Money Order must be drawn for $26.54.

II. For the remittance of £9 15*s.* 7*d*, the Money Order must be drawn for $47.48, *i.e.*, for £9 15*s.*, add to this 7*d.* = 14 c. = $47.62.

It is perhaps of interest to note that

1 Sovereign	weighs	123.27447 grains	=	7.9879 grams.
1 Shilling	,,	87.27272	,,	= 5.6554 ,,
1 Penny	,,	145.83333	,,	= 9.4499 ,,

The legal weight of the penny is thus $\frac{1}{3}$ of an ounce, the half-penny $\frac{1}{5}$, and the farthing $\frac{1}{10}$ of an ounce avoirdupois.

APPENDIX

Nautical Measures

Nautical mile (knot) = 6,080 feet	= 1.852 km.
Cable's length (100 fathoms, 600 feet) ...	= 182.87669 m.
Fathom (6 feet)	= 1.828767 m.

Other Measures of Length

1 Link (7.92 inches)	= 20.0164 cm.
1 Hand (4 inches)	= 10.15988 cm.
1 Pace (military 2 ft. 6 inch)	= 76.19862 cm.

Troy Weight

1 Gram	= 0.032151 oz. (0.032) = 0.64301 dwt. (0.64) = 15.4325 grains (15.4)
1 Ounce (480 grains Avop.) ...	= 31.1035 „ (31.1)
1 Pennyweight (24 grains) ...	= 1.155517 „ (1.12

Apothecaries' Weight

1 Gram	= 0.2572 drachm (0.26) = 0.77162 scruple (0.8) = 15.43235 grains (15.4)
1 Ounce (8 drachms)	= 31.1035 grams (31.0)
1 Drachm ℥ (3 scruples)	= 3.88794 „ (3.9)
1 Scruple ℈ (20 grains)	= 1.29598 „ (1.3)
1 Grain	= 0.064791 „ (0.065)

Apothecaries' Fluid Measure

1 Cubic Centimeter	...	= 0.03527 fluid ounce (0.035) 0.28219 fluid drachm (0.3)
1 Cubic Millimeter...	...	= 0.01693 minim.

1 Minim, ♏ (0.91146 grain) = 0.05916 c.c. (0.06)
1 Fluid Drachm, f3 (60 minims) = 3.54958 c.c. (3.55)
1 Fluid Ounce, f℥ (8 drachms) = 28.39661 c.c. (28.4)
1 Gallon (8 pints, 160 fluid ounces) = 4.54346 liters (4.5)

Wine Measure

1 Deciliter	...	...	...	= 0.244522 firkin (0.24)
1 „	...	...	...	= 0.220096 anker (0.22)
1 Hectoliter	...	...	...	= 1.222758 half barrel (1.2)
1 „	...	...	...	= 0.611373 barrel (0.6)
1 „	...	...	...	= 0.407586 hogshead (0.41)

1 Firkin (9 gals.)	...	...	= 40.89114 liters	(41)
1 Anker (10 gals.)	...	...	= 45.4346 „	(45.4)
½ Barrel [kilderkin] (18 gals.)	...		= 81.78228 „	(82)
1 Barrel (36 gals.)	...	...	= 163.56456 „	(164)
1 Hogshead (54 gals.)	...	...	= 245.34684 „	(245)
1 Puncheon (72 gals.)	...	...	= 327.120 „	(327)
1 Butt (108 gals.)	...	...	= 490.680 „	(491)
1 Tun (2 butts)	...	...	= 981.360 „	(981)

Comparison of Metric Units with the United States Weights and Measures.

Although the United States weights and measures are in most cases the same as the British weights and measures, the equivalents adopted by the United States Bureau of Standards differ to a slight extent. The units adopted by the United

States Bureau of Standards are therefore given here.

Measures of Length.

1 Inch	=	25.4001 mm.
		2.54001 cm.
1 Foot	=	30.48012 cm.
,,	=	0.304801 M.
1 Yard	=	0.914402 M.
1 Mile	=	1.60935 M.
1 Millimeter	=	0.03937 inch.
1 Centimeter	=	0.3937 ,,
1 Meter	=	3.28083 feet.
		1.093611 yard.
1 Kilometer	=	0.62137 mile.

Areas.

1 sq. inch	=	645.16 sq. mm.
1 sq. foot	=	9.290 sq. dm.
		0.09290 sq. M.
1 sq. yard	=	0.8361 ,,
1 acre	=	0.4047 Hectare.
1 sq. mile	=	2.590 sq. KM.

Metric to U.S.A.

1 sq. millimeter	=	0.00155 sq. inch.
1 sq. centimeter	=	0.1550 sq. inch.
1 sq. meter	=	10.764 sq. feet.
,, ,,	=	1.1960 sq. yard.
1 hectare	=	2.471 acres.
1 sq. kilometer	=	0.3861 sq. mile.

VOLUMES.

U.S.A. to Metric.

1 cubic inch	=	16.3872 c.c.
1 ,, foot	=	28.32 c. dm.
1 ,, yard	=	0.7645 cubic M.

Metric to U.S.A.

1 cubic millimeter ...	...	=	0.000061	cubic inch.
1 „ centimeter ...	...	=	0.0610	„ „
1 „ decimeter ...	...	=	61.0	„ „
1 „ meter ...	...	=	1.3079	„ yard.

CAPACITIES.

U.S.A. to Metric.

1 liquid ounce ...	...	=	25.574 c.c.
1 dram ...	...	=	3.6967 „
1 scruple...	...	=	1.2322 „
1 quart (liquid) ...	...	=	0.94636 liter.
1 quart (dry) ...	...	=	1.1012 „
1 gallon (liquid)...	...	=	3.78543 liters.
1 peck ...	...	=	8.80982 „
1 bushel ...	...	=	0.35239 hectoliter.

Metric to U.S.A.

1 cubic centimeter	...	=	0.03381 oz.
„ „	...	=	0.2705 dram
„ „	...	=	0.8115 scruple
1 liter ...	...	=	1.05668 quart (liquid)
1 „ ...	...	=	0.9081 quart (dry)
1 „ ...	...	=	0.26417 gallon
1 „ ...	...	=	0.11351 peck
1 hectoliter ...	...	=	2.83774 bushels

COMPARISON OF SCREW THREADS

Whitworth's Standard Threads

Outside Diameter.		Pitch.		Number of Threads.	
Inches.	Centimeters.	Inches.	Millimeters.	Per inch.	Per centimeter.
$\frac{1}{32}$	.08	.0066	.169	150	59.05
$\frac{1}{16}$	.16	.0166	.423	60	20.35
$\frac{1}{8}$	.32	.025	.635	40	15.8
$\frac{3}{16}$	.48	.041	1.06	24	9.45
$\frac{1}{4}$	.63	.05	1.27	20	7.9
$\frac{5}{16}$	.79	.055	1.41	18	7.1
$\frac{3}{8}$	.95	.0625	1.587	16	6.3
$\frac{7}{16}$	1.11	.0714	1.814	14	5.5
$\frac{1}{2}$	1.27	.083	2.116	12	4.7
$\frac{5}{8}$	1.59	.09	2.39	11	4.3
$\frac{3}{4}$	1.90	.1	2.54	10	3.9
$\frac{7}{8}$	2.22	.111	2.822	9	3.55
1	2.54	.125	3.175	8	3.15
$1\frac{1}{8}$	2.86	.142	3.628	7	2.75
$1\frac{1}{4}$	3.18	.142	3.628	7	2.75
$1\frac{3}{8}$	3.5	.166	4.233	6	2.36
$1\frac{1}{2}$	3.81	.166	4.233	6	2.36
$1\frac{5}{8}$	4.13	.2	5.08	5	1.97
$1\frac{3}{4}$	4.45	.2	5.08	5	1.97
$1\frac{7}{8}$	4.76	.222	5.64	$4\frac{1}{2}$	1.77
2	5.08	.222	5.64	$4\frac{1}{2}$	1.77
$2\frac{1}{4}$	5.72	.25	6.35	4	1.58
$2\frac{1}{2}$	6.35	.25	6.35	4	1.58
3	7.62	.285	7.25	$3\frac{1}{2}$	1.38
$3\frac{1}{4}$	8.26	.3077	7.815	$3\frac{1}{4}$	1.28
4	10.16	.333	8.466	3	1.18
5	12.7	.363	9.236	$2\frac{3}{4}$	1.08

WEIGHTS AND PRESSURES USEFUL FOR ENGINEERS

Weights

	Lb.	Long Ton.	Short Ton.	Kilograms.	Metric Tons.
1 lb. (av.)	1	0.000446	0.0005	0.4536	0.0004536
1 ton (long ton)	2240	1	1.14	1,016	1.016
1 ton (short ton)	2000	0.89285	1	907.2	0.9072
1 kilogram	2.205	0.000984	0.000907	1	0.001
1 metric ton	2205	0.9842	1.102	1000	1

PRESSURES

	Lb. per sq. inch.	Kgs. per sq. cm.	Inches of Mercury.	Mms. of Mercury.
1 lb. per sq. inch	1	0.0703	2.036	51.71
1 kg. per sq. cm.	14.22	1	28.96	735.5
1 inch of mercury	0.4912	0.0345	1	25.4
1 mm. of mercury	0.0193	0.00136	0.03937	1
1 atmosphere	14.706	1.033	29.92	760

For the unit of power one cannot do better than employ the kilowatt (K.W.) which is much more rational than the horse-power (H.P.). We give below a table showing the values of various units in watts, which is taken from "Steam Turbine Engineering," by Stevens and Hobart. The next four tables are adapted from Molesworth's Metric System Tables.

Unit.	Abbreviation.	Value in watts.
1 kilowatt	1 K.W.	1000
1 kilogram-calorie per second ...	1 Kg. C. S.	4190
1 kilogram-meter per second ...	1 Kg. M. S.	9.81
1 horse-power	1 H.-P.	746
1 British thermal unit per second	1 B. Th. U. S.	1055
1 foot-pound per second ...	1 ft. lb. s.	1.356

TABLE OF ATMOSPHERES EQUIVALENT TO POUNDS PER SQUARE INCH.

Lbs. per sq. in.	0	1	2	3	4	5	6	7	8	9
0		0.068	0.136	0.204	0.272	0.340	0.408	0.476	0.544	0.612
10	0.680	0.748	0.816	0.884	0.952	1.020	1.088	1.156	1.224	1.292
20	1.360	1.428	1.496	1.564	1.632	1.700	1.768	1.836	1.904	1.972
30	2.040	2.108	2.176	2.244	2.312	2.380	2.448	2.516	2.584	2.652
40	2.720	2.788	2.856	2.924	2.992	3.060	3.128	3.196	3.264	3.332
50	3.400	3.468	3.536	3.604	3.672	3.740	3.808	3.876	3.944	4.012
60	4.080	4.148	4.216	4.284	4.352	4.420	4.488	4.556	4.624	4.692
70	4.760	4.828	4.896	4.964	5.032	5.100	5.168	5.236	5.304	5.372
80	5.440	5.508	5.576	5.644	5.712	5.780	5.848	5.916	5.984	6.052
90	6.120	6.188	6.256	6.324	6.392	6.460	6.528	6.596	6.664	6.732

TABLE OF POUNDS PER SQUARE INCH EQUIVALENT TO ATMOSPHERES.

Atmospheres.	0	1	2	3	4	5	6	7	8	9
0		14.706	29.412	44.118	58.824	73.530	88.236	102.942	117.648	132.354
10	147.060	161.766	176.472	191.178	205.884	220.590	235.296	250.002	264.708	279.414
20	294.120	308.826	323.532	338.238	352.944	367.650	382.356	397.062	411.768	426.474
30	441.180	455.886	470.592	485.298	500.004	514.710	529.416	544.122	558.828	573.534
40	588.240	602.946	617.652	632.358	647.064	661.770	676.476	691.182	705.888	720.594
50	735.300	750.006	764.712	779 418	794.124	808.830	823.536	838.242	852.948	867.654
60	882.360	897.066	911.772	926.478	941.184	955.890	970.596	985.302	1000.01	1014.71
70	1029.420	1044.13	1058.83	1073.54	1088.24	1102.95	1117.66	1132.36	1147.07	1161.77
80	1176.480	1191.19	1205.89	1220.60	1235.30	1250.01	1264.72	1279.42	1294.13	1308.83
90	1323.540	1338.25	1352.95	1367.66	1382.36	1397.07	1411.78	1426.48	1441.19	1455.89

TABLE OF SQUARE FEET EQUIVALENT TO SQUARE METERS.

Square Meters.	0	1	2	3	4	5	6	7	8	9
0		10.7643	21.5286	32.2929	43.0572	53.8215	64.5858	75.3501	86.1144	96.8787
10	107.643	118.407	129.172	139.936	150.700	161.465	172.229	182.993	193.757	204.522
20	215.286	226.050	236.815	247.579	258.343	269.108	279.872	290.636	301.400	312.165
30	322.929	333.693	344.458	355.222	365.986	376.751	387.515	398.279	409.043	419.808
40	430.572	441.336	452.101	462.865	473.629	484.394	495.158	505.922	516.686	527.451
50	538.215	548.979	559.744	570.508	581.272	592.037	602.801	613.565	624.329	635.094
60	645.858	656.622	667.387	678.151	688.915	699.680	710.444	721.208	731.972	742.737
70	753.501	764.265	775.030	785.794	796.558	807.323	818.087	828.851	839.615	850.380
80	861.144	871.908	882.673	893 437	904.201	914.966	925.730	936.494	947.258	958.023
90	968.787	979.551	990.316	1001.08	1011.84	1022.61	1033.37	1044.14	1054.90	1065.67

TABLE OF SQUARE METERS EQUIVALENT TO SQUARE FEET.

Square Feet.	0	1	2	3	4	5	6	7	8	9
0		0.092900	0.185799	0.278699	0.371599	0.464498	0.557398	0.650298	0.743197	0.836097
10	0.9289968	1.02190	1.11480	1.20770	1.30060	1.39350	1.48639	1.57929	1.67219	1.76509
20	1.857994	1.95089	2.04379	2.13669	2.22959	2.32249	2.41539	2.50829	2.60119	2.69409
30	2.786990	2.87989	2.97279	3.06569	3.15859	3.25149	3.34439	3.43729	3.53019	3.62309
40	3.715987	3.80889	3.90179	3.99469	4.08759	4.18049	4.27339	4.36628	4.45918	4.55208
50	4.644984	4.73788	4.83078	4.92368	5.01658	5.10948	5.20238	5.29528	5.38818	5.48108
60	5.573981	5.66688	5.75978	5.85268	5.94558	6.03848	6.13138	6.22428	6.31718	6.41008
70	6.502978	6.59588	6.68878	6.78168	6.87458	6.96747	7.06037	7.15327	7.24617	7.33907
80	7.431974	7.52487	7.61777	7.71067	7.80357	7.89647	7.98937	8.08227	8.17517	8.26807
90	8.360971	8.45387	8.54677	8.63967	8.73257	8.82547	8.91837	9.01127	9.10417	9.19707

Meters per Second.	Kilometers per Hour.	Miles per Hour.	Feet per Minute.	Feet per Second.	Meters per Second.	Kilometers per Hour.	Miles per Hour.	Feet per Minute.	Feet per Second.
1	3.6	2.24	197	3.28	51	183.6	114.2	10050	167.3
2	7.2	4.48	394	6.56	52	187.2	116.5	10240	170.6
3	10.8	6.72	591	9.84	53	190.8	118.7	10440	173.8
4	14.4	8.96	788	13.1	54	194.4	121.0	10640	177.1
5	18.0	11.2	985	16.4	55	198.0	123.2	10840	180.5
6	21.6	13.4	1180	19.7	56	201.6	125.4	11030	183.7
7	25.2	15.7	1380	24.0	57	205.2	127.7	11230	187.0
8	28.8	17.9	1580	26.2	58	208.8	129.9	11430	190.2
9	32.4	20.2	1780	29.5	59	212.4	132.2	11620	193.5
10	36.0	22.4	1970	32.8	60	216.0	134.4	11820	196.8
11	39.6	24.6	2170	36.1	61	219.6	136.6	12020	200.1
12	43.2	26.9	2360	39.4	62	223.2	138.9	12210	203.4
13	46.8	29.1	2561	42.6	63	226.8	141.1	12410	206.6
14	50.4	31.4	2760	45.9	64	230.4	143.4	12610	209.9
15	54.0	33.6	2960	49.2	65	234.0	145.6	12810	213.2
16	57.6	35.8	3152	52.5	66	237.6	147.8	13000	216.5
17	61.2	38.1	3350	55.8	67	241.2	150.1	13200	219.8
18	64.8	39.3	3550	59.0	68	244.8	152.3	13400	223.0
19	68.4	42.6	3740	62.3	69	248.4	154.6	13590	226.3
20	72.0	44.8	3940	65.6	70	252.0	156.8	13790	229.6
21	75.6	47.0	4140	68.9	71	255.6	159.0	13990	232.9
22	79.2	49.3	4334	72.2	72	259.2	161.3	14180	236.2
23	82.8	51.5	4530	75.4	73	262.8	163.5	14380	239.4
24	86.4	53.8	4730	78.7	74	266.4	165.8	14580	242.7
25	90.0	56.0	4930	82.0	75	270.0	168.0	14780	246.0
26	93.6	58.2	5120	85.3	76	273.6	170.2	14970	249.3
27	97.2	60.5	5320	88.6	77	277.2	172.5	15170	252.6
28	100.8	62.7	5520	91.8	78	280.8	174.7	15370	255.8
29	104.4	65.0	5710	95.1	79	284.4	177.0	15560	259.1
30	108.0	67.2	5910	98.4	80	288.0	179.2	15760	262.4
31	111.6	69.5	6110	101.9	81	291.6	181.4	15960	265.7
32	115.2	71.7	6300	105.0	82	295.2	183.7	16150	269.0
33	118.8	73.9	6500	108.2	83	298.8	185.9	16350	272.2
34	122.4	76.2	6700	111.5	84	302.4	188.2	16550	275.5
35	126.0	78.4	6900	114.8	85	306.0	190.4	16750	278.8
36	129.6	80.6	7090	118.1	86	309.6	192.6	16940	282.1
37	133.2	82.9	7290	121.4	87	313.2	194.9	17140	285.4
38	136.8	85.1	7490	124.6	88	316.8	197.1	17340	288.6
39	140.4	87.4	7680	127.9	89	320.4	199.4	17530	291.9
40	144.0	89.6	7880	131.2	90	324.0	201.6	17730	295.2
41	147.6	91.8	8080	134.5	91	327.6	203.8	17930	298.5
42	151.2	94.1	8270	137.8	92	331.2	206.1	18120	301.8
43	154.8	96.3	8470	141.0	93	334.8	208.3	18320	305.0
44	158.4	98.6	8670	144.3	94	338.4	210.6	18520	308.3
45	162.0	100.8	8870	147.6	95	342.0	212.8	18720	311.6
46	165.6	103.0	9060	150.9	96	345.6	215.1	18910	314.9
47	169.2	105.3	9260	154.2	97	349.2	217.3	19110	318.2
48	172.8	107.5	9460	157.4	98	352.8	219.5	19310	321.4
49	176.4	109.8	9650	160.7	99	356.4	221.8	19500	324.7
50	180.0	112.0	9850	164.0	100	360.0	224.0	19700	328.0

Thermal Units.

The Small Calorie is the amount of heat required to raise the temperature of one gram of water one degree Centigrade.

The Large Calorie is the amount of heat required to raise the temperature of one kilogram of water through one degree Centigrade. Consequently it is one thousand times greater than the small calorie.

The British Thermal Unit (B.T.U.) is the amount of heat required to raise the temperature of one pound of water through one degree Fahrenheit. Now, as one kilogram is equal to 2.20462 pounds, and one degree Centigrade is equal to 1.8° Fahrenheit, therefore the large calorie is $1.8 \times 2.20462 = 3.968316$ times as great as the British Thermal Unit, and the small calorie is 0.003968316 of the B.T.U.

The Heat of Combustion of a substance is the number of small or large calories, as the case may be, of heat evolved during the combustion of 1 gram or kilogram of the substance.

By employing the English weights and measures, it is the number of British Thermal Units evolved during the combustion of the substance. To convert calories into B.T.U., multiply by 1.8, and conversely to convert B.T.U. into calories, divide by 1.8.

Specific Gravities

Metals

Aluminium	2.58
Antimony	6.62
Bismuth	9.78
Cadmium	8.65
Chromium	6.92
Copper	8.93
Gold (pure cast)	19.30
Iron (cast)	7.21
„ (bars)	7.79
„ (rolled plates)	7.70
Lead	11.36
Magnesium	1.75
Mercury	13.59
Nickel	8.25—8.8
Platinum	21.4
Silver	10.47
Steel plates	7.81
Steel wire	7.85
Tin	7.29
Zinc (cast)	6.86
„ (rolled)	7.20

Non-Metals

Chalk	1.52—2.78
Coal (anthracite)	1.44
Flint	2.5
Glass (bottle)	2.73
„ (crown)	2.49
„ (window)	2.64
Marble	2.70
Plumbago	2.1
Quartz	2.66
Slate	2.67—2.90
Stone (Bath)	1.96
„ (Portland)	2.37
„ (sandstone)	2.2
Sulphur (native)	2.03

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